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Calvin F. Swingle
EDITOR IN-CHIEF

ASSISTED BY A CORPS OF
MECHANICAL EXPERTS

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HOW TO REPAIR

LOCOMOTIVE BREAKDOWNS

Giving a Complete Description of Every Possible Form of Breakdown and the Best Method for Quick Repair, Taken from Actual Experience

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VOL. VI

ILLUSTRATED

BY

CALVIN F. SWINGLE, M. E.

AND A CORPS OF PRACTICAL MECHANICAL EXPERTS

PUBLISHERS

NATIONAL INSTITUTE OF PRACTICAL MECHANICS

CHICAGO, ILL.

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Copyright Entry
Aug. 24, 1908
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216978
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CHICAGO, ILLINOIS

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PREFACE.

The importance and value of education cannot be overestimated. The time has come when men must learn to profit by the knowledge and experience of others in their own particular field of endeavor as a supplement or complement to their own observation and experience. This fact is clearly and ably set forth in a forcible and interesting manner by Mr. Conger whose valuable paper has been incorporated in this volume. Hence the reason for gathering together from every available source the subject-matter in this book. It will be seen that some of the topics are preceded by a regular series of questions and answers, some of which while not specifically treating of breakdowns lead up to and have a direct bearing thereon. In a few instances explanatory articles and descriptions with illustrations have been introduced. This has been done because questions and answers have their limitations. The editors make no pretense to originality, and possibly the criticism may be made that in one or two cases the methods advocated do not now apply. This may be true on large and modern well-equipped roads, but it should be remembered that this work may be perused by men less fortunate with regard to modern equipment. It may be noticed likewise that nothing is said regarding troubles with Air Brakes. This is because in the volume devoted to that subject in this work, that phase of Air Brake operation is fully and thoroughly covered in question and answer style.

The various topics have been grouped and arranged in a manner which it is hoped will render easy reference

possible, and as some of the questions answered by Mr. W. G. Wallace through the columns of the Brotherhood of Locomotive Firemen's Magazine throw sidelights on certain subjects, because of peculiar circumstances which prompted the questions, it has been deemed best to give them, even at the risk, in some cases, of repetition.

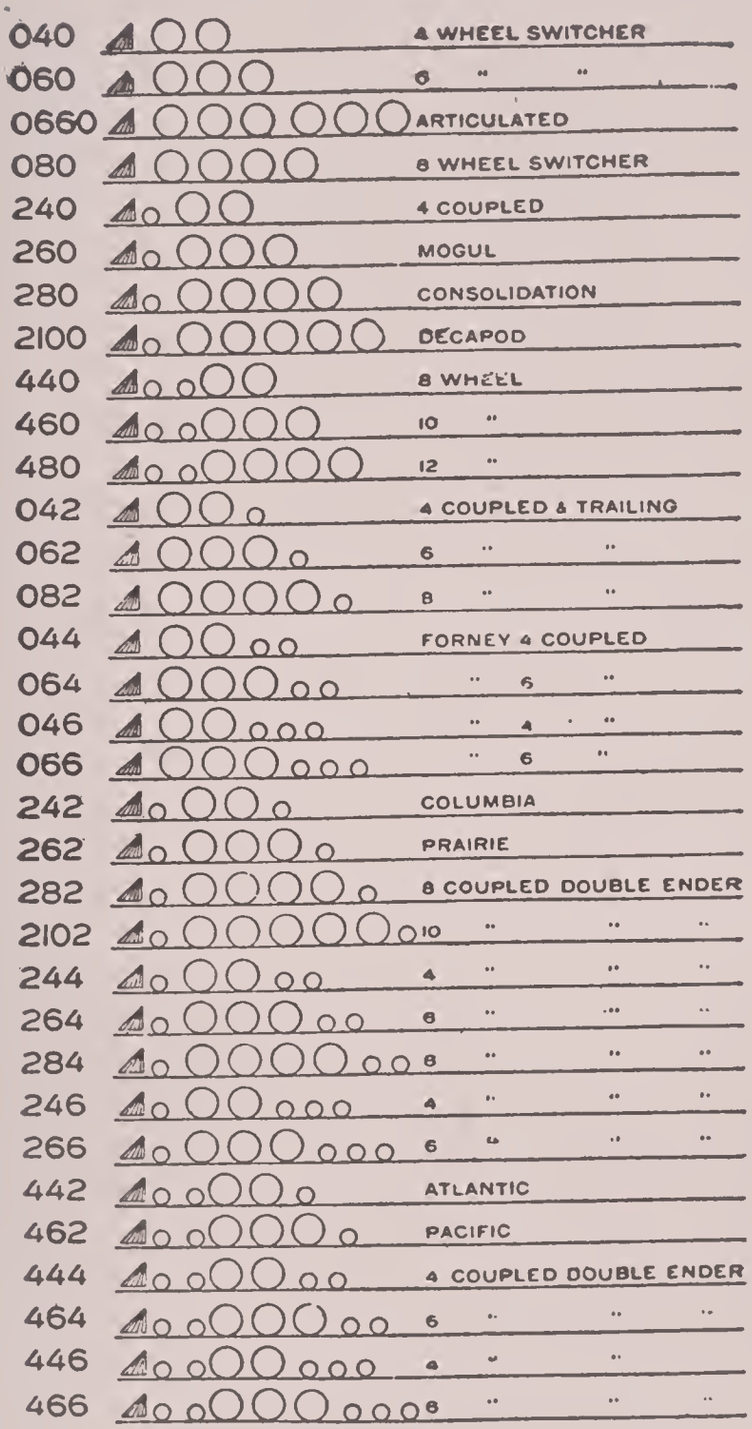
To all sources from which the editors have drawn, and to the editor of the Locomotive Firemen's and Enginemen's Magazine for courtesies extended, grateful acknowledgment is made.

AMERICAN LOCOMOTIVE COMPANY

ENGINEERING DEPARTMENT

CLASSIFICATION OF LOCOMOTIVES

(WHYTE'S SYSTEM)



The locomotive classification adopted by the American Locomotive Company is based on the representation by numerals of the number and arrangement of the wheels commencing at the front. Thus 260 means a Mogul and 460 a ten-wheel engine, the cipher denoting that no trailing truck is used.

The total weight is expressed in 1,000 of pounds. Thus an Atlantic locomotive weighing 176,000 pounds would be classified as a 442-176 type. If the engine is Compound the letter C should be substituted for the dash thus 442 C 176. If tanks are used in place of a separate tender the letter T should be used in place of the dash. Thus a double end suburban locomotive with two-wheeled leading truck, six drivers and six-wheeled rear truck, weighing 214,000 pounds, would be a 266 T 214 type.

*INFLUENCE OF EDUCATION ON THE WORK OF AN ENGINEER AND FIREMAN AS A FACTOR IN HIS SUCCESS.

Education is defined as the acquiring of knowledge. Knowledge may be acquired from the work of others, from our own experience, from the use of text books and in a general way from the reading of technical publications and the newspaper discussion of any facts in the operation of nature. A practical education can be very different from a theoretical one and usually is, but each kind has its own value and each one taken separately is only a part of a complete education.

The man who has acquired his education in any branch of work requiring skill by actually performing the operations over and over again till he is proficient, is apt to value the theoretical part of an education too low; on the other hand, the man who has taken up the study of the theory of any operation from the beginning and followed up all the various steps, but has not actually performed manually or seen worked out all the operations, will give the theoretical education too much credit. It is the easiest and quickest way for him and therefore he is sure it is the best.

It is to the man who can combine the theoretical and practical sides of an education that we look for the best results, because we are sure that he is the best equipped.

Every well educated man has as a result of his learning

*Paper by C. B. Conger, read before the Traveling Engineers' Assn., August, 1908.

a sort of judicial turn of mind in that he can balance the cost and results of all operations and decide on the way that gets the best results with the least expenditure of thought and labor, or of headwork and handwork.

We must not pass lightly by the word "thorough" as applied to an education in our subject, for on the thoroughness of an education does its value depend. An education is not knowing a whole lot of things, some of which are wrong, but it is knowing a lot of facts, every one of which is right. If we know about only a few of the points of interest in an operation, we are only partly educated; if we see only the surface, our knowledge is superficial and of little use. For instance, we may have a good idea of the outside of an air pump, but unless we also know about its interior construction our knowledge helps us little. As long as it works all right we may think we do not need to know much about it, but if it does not work, our superficial or outside knowledge is useless.

Then there is another type of education that we might call "spasmodic." It takes a great hold on the mind for a few hours or at best for a few months, and is then forgotten and lost. This kind of an education is acquired by listening to a detailed explanation and not paying close attention to the various processes and how they depend on each other, or by reading a text book through in a few hours without giving the details proper consideration as we go along. It is this habit of reading a text book through at a gallop with no other motive than a curiosity to see if the author says anything that you have not seen before that gives so much discredit to book learning, when the fact is there is no book learning in the process—it is only book skimming. The man who uses such slip-shod methods of educating himself is apt to be more slip-shod

in his use of what education he acquires and not a very safe man to trust.

In a machine shop or factory a large part of the workers are kept at one machine or in the production of one article, so that they become specially skillful in that one line, but know very little about the other branches of the work necessary to turn out a complete machine. This we might call a partial education. The man on the locomotive, however, has to know about all the details of his work and about all the parts of the machine, both as to the operation and to the construction as far as the construction affects caring for the machine when it is disabled; he must also know about it as a complete whole. There is no telling beforehand just what part of a locomotive is liable to break down next and the man in charge must have the proper remedy ready at once—not wait until some one comes along and shows him his lame point.

If a man has only a partial knowledge of the proper methods and something happens that is new to him he fails entirely. Because there are men handling locomotives and seem to be successful that do not know all they can if they would, is no excuse for it. The fact they are the only ones who regard them as successful, no one else dares to, they are only partly successful, and the other brighter ones have to help them out all the time. It is a saying among railroad officers that the fast limited trains going over the road every day "key up all the employees to a high pitch every time they pass and in that way help the service to better dispatch and safer conditions for all the other trains on the road." In the same way one or two skillful, well-posted engineers on a division who know how they do their work and can give a reason for everything they do in the handling of a train, will key up all

the others, partly from association, but more because the others first observe how the skillful men do their work and then try to copy their methods. Will it not be true then that a thorough education will make the men on the engine more successful?

Talking about the safety of railroading, which is the safest road to work on, the one where all the men engaged in the train service are bright and well-posted in their business, or the road where a percentage are in doubt as to whether what they know is right or wrong? We are proud of the fact that the standard of our enginemen is high and that they are putting it higher of their own account. Is it not our duty to help raise that standard? Should we not pay more attention to arranging for furnishing information on the latest and most correct methods of handling trains and locomotives and systematizing this information so that it can be easily reached by the men we expect will use it?

When the poorly informed man begins to observe how the more skillful man does his work, to use a slang phrase, he "begins to sit up and take notice," and is taking his first step in his education in that line. The next step after the observation (if he is in earnest) is to search for the source of the other man's superior skill, and on his ability to copy the successful methods depends his value, not as a copyist, but as an operator.

A great deal used to be said about learning from experience, because then there was no other source of learning, text books were very few and of a very poor quality, as their grammatical construction was more carefully looked after than their mechanical accuracy. Nowadays text books and instruction books are so numerous as to almost crowd up against you. Experience as the only teacher

is only a poor excuse today. A railroad man cannot live long enough to experience all the breakdowns that can happen to a locomotive. The man who raises the loudest hurrah for experience as the only teacher generally suffers most from his method in his early schooling, for his "experience consists in having an engine break down and tie up the road for a time and then after the investigation serving from ten to thirty days for a lack of knowing how."

Most men will agree with the statement that all the facts you should know about an engine cannot be learned by your own experience and the next resort is someone else's experience. As you cannot have seen all he has done all his life as an engineer, you must depend on his telling it to you, and it is a solid fact that a fireman who fires for a skillful engineer who takes pains to tell him of all possible breakdowns and how he would get the train and engine in, is a better man when promoted than if he depends on his own ideas and experience. Now if telling the beginner how to do his work helps him out, the same facts can be given him on the printed page, and let his eyes tell the story to his thinking machine, the brain, instead of depending on his ears only. The ears hear it only once, but the eyes can go over the printed page that explains the details of a locomotive a dozen times if necessary and get it just right each time. Another advantage is that the printed page can be furnished to every young man when he goes to work, while we cannot furnish an instructor for each beginner.

Today thanks to the growth of the idea that an education is necessary for every railroad man, information is spread broadcast by text books and schools, magazines, technical journals, associations like the Traveling Engi-

neers' Association and the Railway Clubs. It is a good sign that the labor organizations among railway employees in their fraternal publications pay so much attention to the education of their members in matters of train and locomotive operations, and they are doing much good in this way.

Knowledge is indeed spreading and there is no doubt that it is the opinion of both officers and employees that knowledge is a good thing to have as well as to search after.

The spread and use of technical and practical education reminds us of the New Testament parable of the Sower who went forth to sow seed. Some of it fell by the wayside and was eaten up by the fowls of the air, the men who care not for the morrow, but for the present moment only. Some fell on stony ground where there was no nourishment so that it did not grow to full size as an idea and help the stony ground man. Some information and ideas fall among the thorns and thistles of willful ignorance and are quickly choked. Thanks to our young, pushing, brainy men in railway service, the ideas that fall on good ground grow and bring forth other good, strong ideas, some fifty-fold and some a hundred-fold. An advantage that is manifest to a man early in his education is that education trains and disciplines the mind so that it is better able to grasp new ideas and make good use of them. The fireman who studies and thoroughly masters the subject of soft coal burning or combustion is better fitted to master the mechanical problems when he comes to them. And now, how far does the advantage of a thorough education in railway operations influence the success of the man on the locomotive?

Safety is the first thing to look for in railway opera-

tions. A thoroughly educated man, not in theories and formulas, but who knows all the ins and outs of train handling, is sure of his methods. This gives him confidence when doing his work, and confidence is another name for courage. With confidence in your machine and your methods of handling it, or, what comes next to it, confidence in your methods even if your machine is not a strictly first-class one, the bugbear of the young runner, getting rattled in the face of danger, is put to one side and you are as cool and clearheaded in the face of danger as though everything were smooth sailing. How often have we seen or known one of the veterans of the throttle in a dangerous place with a train and his skill, that is the result of long years of education in his business, enabled him to do the right thing at the right time and not too late to save from a smash-up! As we all know who have served on the deck of a locomotive, we have to think of two or more things in a brief instant and think right both times to save life and property.

When an engineer or fireman is not thoroughly educated in good methods of train handling he is timid in the face of danger, always nervous and looking for trouble, not so much because he expects it, but because he is afraid to meet it. Now, if a thorough education in railroading will give a man confidence and skill in the face of danger, it is surely worth while. Once in a while we hear of a man who does not know enough of his machine to be afraid, but he is not the one who makes the reputation of his road; it is the man who really knows. It is an old proverb that a little knowledge is a dangerous thing. Learn all the facts that you can; the best and most will not make any one of us too competent or teach us too much.

Economy comes second after safety. A thorough education will enable an engineer or fireman to get the best results from the locomotive, and in these strenuous times anything less than the best is not good enough. While the first pound of steam in a boiler counts as a pound, yet it is not half as much sought after as the last pound we can get in it just before the pop begins to sing its busy song.

Correct knowledge of how much coal and water it takes to move a certain train from one stopping place to another would save many useless tops, or, what is expensive, cutting off and running for water. A thorough knowledge of the construction and strains on the machinery and running gear of a locomotive will save stripping an engine either by accident or design when some minor parts are disabled or disconnected.

Skill with the scoop means economy in the use of fuel, but better still, it means a good steamer, while a lack of knowledge makes a poor steamer. It takes steam to move trains and plenty of steam means quick dispatch, which is a much-neglected form of economy in these days of heavy tonnage trains that move so slowly that they tie up the road and keep the yards blocked.

Then the steam when skillfully made by the fireman must be skillfully and economically distributed in the cylinders if we wish to get power and speed from the steam to the train.

Skill in handling the reverse lever and throttle gets as many heavy trains in on time as big locomotives carrying a high steam pressure. Skill with the injector counts for as much as skill with the scoop if the steam gauge is any guide.

To get the best results, skill is needed with all the

devices that help to make up the complex machine that the engineer and fireman handle every trip, and in every case a thorough education is the real factor in making a man skillful. Railroading is with some an occupation, something to earn a living at; with others it is a trade and they learn enough to work at it and go through the motions in a mechanical sort of a way. But, it is really a profession as much as either law or medicine, and a man should be as practically and thoroughly educated as in any profession, in order to be successful.

The Traveling Engineers present should remember that the young men in your charge, and some of the middle aged ones, too, are hungry for accurate information, and while they are ready to learn you fall short of doing your full duty if you do not encourage them, at least in private if not publicly.

To the engineman I would say: As an engineer, who is proud of his craft you can get a thorough education if you want it. The world owes you one and it will always pay you to go after it.

TRAIN RESISTANCE.

The actual resistance to be overcome by a moving train, can never be absolutely known. It depends upon so many factors, some of which vary to so great an extent with ever changing conditions, that it can be calculated only approximately. For all practical working purposes, however, an approximate knowledge is all that is needed, provided a safe margin be allowed for possible error; and the train operator may leave all fine theorizing and measurements to the experimental laboratory and the engineering school.

Resistance is due to several causes—rolling friction of wheel on rail, friction of journals, internal engine friction, back pressure of steam, force of gravity in ascending grades, effect of curves in track, necessity of getting up greater speed, and, finally, the resistance of the atmosphere.

The accompanying table will be found useful in estimating train resistance for various speeds and grades, on both straight and curved track. The column of resistance "due to speed only" (*i. e.*, on level, straight track) probably represents fairly the resistance of average loaded cars under favorable conditions. For heavily loaded cars of the best construction, running on heavy rails and first-class roadbed, the resistance may be less than the figures given. On the other hand, with empty cars, in bad weather, or on a poor roadbed, the resistance may be greatly increased. In using the table, allowance should be made for the probable error due to such variations in resistance.

TABLE OF TRAIN RESISTANCE.

Resistance of Trains in Pounds per Ton (of 2000 Pounds) for Various Speeds and Grades. Straight Track.

Speed, Miles per Hour.	Resistance Due to Speed Only.	Per Cent. of Grade.																																		
		.09	.19	.28	.38	.57	.76	.95	1.14	1.33	1.52	1.71	1.89	2.08	2.27	2.46	2.65	2.84	3.03	3.22	3.41	3.60	3.79	3.98	4.17	4.36	4.55	4.74	4.92	5.11	5.30	5.49	5.68
		Grade in Feet per Mile.																																		
		5	10	15	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300			
		Resistance due to Grade Only.																																		
		1.89	3.79	5.68	7.58	11.36	15.15	18.94	22.73	26.52	30.30	34.09	37.88	41.67	45.45	49.24	53.03	56.82	60.60	64.40	68.18	71.97	75.76	79.55	83.34	87.12	90.91	94.70	98.48	102.27	106.06	109.85	113.63			
		Resistance due to Grade and Speed.																																		
10	5.0	6.9	8.8	10 7	12 6	16.4	20 2	23.9	27 7	31.5	35.3	39 1	42.9	46.7	50.5	54 2	58.0	61 8	65 6	69 4	73 2	77 0	80.8	84.6	88 3	92.1	95.9	99.7	103.5	107.3	111.1	114.9	118.6			
15	5.5	7 4	9.3	11 2	13.1	16 9	20.7	24.4	28.2	32.0	35.8	39 6	43.4	47.2	51.0	54.7	58.5	62.3	66 1	69 9	73.7	77.5	81.3	85.1	88.8	92.6	96.4	100.2	104.0	107.8	111.6	115.4	119.1			
20	6 2	8.1	10.0	11.9	13.8	17.6	21 4	25.1	28.9	32.7	36.5	40.3	44.1	47.9	51.7	55 4	59 2	63.0	66.8	70 6	74 4	78.2	82.0	85.8	89.5	93.3	97.1	100.9	104.7	108.5	112.3	116.1	119.8			
25	7.0	8.9	10.8	12.7	14.6	18 4	22.2	25.9	29.7	33.5	37.3	41.0	44.9	48.7	52.5	56 2	60 0	63.8	67 6	71 4	75 2	79.0	82.8	86.6	90.3	94 1	97.9	101.7	105.5	109.3	113.1	116.9	120.6			
30	8 0	9.9	11 8	13 7	15.6	19.4	23.2	26.9	30.7	34.5	38 3	42.1	45.9	49.7	53 5	57.2	61 0	64.8	68 6	72.4	76 2	80.0	83.8	87 6	91.3	95.1	98.9	102.7	106.5	110.3	114.1	117.9	121.6			
35	9 1	11.0	12 9	14.8	16.7	20.5	24.3	28.0	31.8	35.6	39.4	43.2	47 0	50.8	54.6	58.3	62.1	65.9	69 7	73 5	77.3	81 1	84.9	88 7	92.4	96.2	100.0	103.8	107.6	111.4	115.2	119.0	122.7			
40	10 4	12 3	14 2	16.1	18.0	21.8	25.6	29.3	33.1	36.9	40.7	44.5	48.3	52.1	55.9	59.6	63 4	67 2	71.0	74.8	78.6	82.4	86.2	90.0	93.7	97.5	101.3	105.1	108.9	112.7	116.5	120.3	124.0			
45	11.8	13 7	15.6	17.5	19.4	23.2	27.0	30.7	34.5	38.3	42.1	45.9	49.7	53.5	57 3	61.0	64 8	68.6	72.4	76 2	80.0	83.8	87.6	91.4	95.1	98.9	102.7	106.5	110.3	114.1	117.9	121.7	125.4			
50	13 4	15 3	17 2	19 1	21 0	24 8	28.6	32.3	36 1	39.9	43.7	47.5	51.3	55.1	58.9	62.6	66.4	70.2	74 0	77.8	81.6	85.4	89.2	93.0	96.7	100.5	104.3	108.1	111.9	115.7	119.5	123.3	127.0			
60	17 0	18 9	20 8	22.7	24 6	28 4	32.2	35.9	39.7	43.5	47 3	51 1	54.9	58.7	62.5	66 2	70.0	73 8	77 6	81 4	85 2	89 0	92 8	96 6	100.3	104 1	107.9	111.7	115.5	119.3	123.1	126.9	130.6			

Degree of Curve	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Radius of Curve	5730	2865	1910	1433	1146	955	819	717	637	574	522	478	442	410	383	359	338	320	303	288	274	262	251	240	231	222
Equivalent Grade	1.32	2.64	3.96	5.28	6.60	7.92	9.24	10.56	11.81	13.20	14.52	15.84	17.16	18.48	19.80	21.12	22.44	23.76	25.08	26.40	27.72	29.04	30.36	31.68	33.00	34.32

Curve Resistance—½ pound per ton per degree of curve Equivalent grade in feet per mile—1.32 x degree of curve Grade resistance—.5788 pounds per foot of grade.

NOTE.—The column of resistance due to speed includes all resistances of locomotive and train except internal engine friction. The figures are probably nearly correct for passenger cars and medium loaded freight cars, under favorable conditions. For heavily loaded freight cars the resistance may be less than the figures given, but for empty cars, or in bad weather, they may be considerably greater. The proportion of resistance due to grade is correct for all conditions, and consequently the possible percentage of error in using above figures is less for heavy grades than for light.

As the resistance due to grade is simply the force necessary to lift the weight of the train the height of the ascent, this is something that is accurately known, so that in calculating resistance for heavy grade work the chances of error are proportionately less than for light grades or levels.

Roughly speaking, the resistance due to grade (in pounds per ton) will be 20 times the per cent. of grade, or .3788 times the grade in feet per mile. Thus, on a 3.6 per cent. or 190-foot, we have:

Resistance due to grade=20×3.6=190×.3788=72 lbs. per ton.

This resistance due to grade has, of course, to be added to the resistance due to speed only (or on level track), in calculating the actual resistance to be overcome by a train ascending grade. Thus, turning to the table, we find that a train running at 40 miles per hour would have a resistance of only 10.4 lbs. per ton on level track; but in ascending a 2.08 per cent. or 110-foot grade, would have to overcome a resistance of 10.4+41.67=52.07 (practically 52.1) lbs. per ton.

In the case of curves, the lower table enables us to find the *equivalent grade* for various degrees or radii of curves; whereupon the upper table will give the resistance due to such equivalent grade. The curve resistance can also be roughly estimated at one-half pound per ton per degree of curve.

AIR RESISTANCE TO MOVING TRAINS.

The most uncertain factor in all calculations of train resistance is the effect of the resistance offered by the atmosphere. There is a tendency to overlook the importance of this factor, but it is one of great significance.

In the case of high-speed trains, it is claimed, the atmospheric resistance may amount to one-half the total resistance.

Experiments made on European roads have led to the conclusion that after a car has been started it requires a force of about 4 to 6 pounds to keep it moving slowly. As the speed increases, a greater force is necessary, since the resistance of the air increases as the square of the velocity. That is, if a train is made to move twice as fast, the resistance becomes 2x2 (or 4) times as great; if made to move three times as fast, it becomes 3x3 (9) times as great; and so on. Thus, at a speed of 60 miles an hour, the resistance will be four times as great as at 30 miles.

On the other hand, as speed increases, the power of a locomotive also increases, but only up to a certain limit; if the speed is increased beyond that limit, the power of the locomotive declines. It is estimated that a locomotive has developed its maximum of power when a speed of 21¾ miles per hour is reached.

Perhaps the most important data ever gathered on the subject of atmospheric resistance to moving trains, is based on experiments conducted during the winter of 1895-96, in the Engineering Laboratory at Purdue University, Lafayette, Ind., by Prof. H. C. Solberg, assisted by Mr. Augustus C. Spiker and Norman E. Gee.

For the purposes of the experiments, a rectangular conduit was constructed, within which a current of air having any desired velocity could be maintained. Within this conduit, and exposed to the action of the air currents, small dummy or model cars were mounted, each model being connected with a sensitive dynamometer recording the value of any force tending to displace it in the direction of its length.

Below we give a partial summary of the more important conclusions. The figures given apply to trains and parts of trains having an area of cross-section equal to that common in American practice. They are, however, general in character; and when applied to individual cases, may lead to errors of from 15 to 20 per cent. The possibility of such errors should in every case be considered in making final estimates. The conclusions are as follows:

1. The resistance offered by still air to the progress of a locomotive and tender running at the head of a train is approximately ten times greater than that acting on an intermediate car of same train.

2. The resistance offered by still air to the progress of the last car of a train, is approximately two and one-half times greater than that acting on an intermediate car of same train.

3. To calculate the resistance offered by still air to the progress of trains and parts of trains, first ascertain the velocity of the train in miles per hour, and "square" it, *i. e.*, multiply the velocity by itself; then multiply the result by various factors according to the particular case, as follows:

For	Multiply Sq. of velocity by
Locomotive and tender running alone	.13
Locomotive and tender at head of train	.11
Last car of freight train	.026
Last car of passenger train	.036
Each intermediate freight car in train of 33-foot cars	.01
Each intermediate passenger car in train of 66-foot cars	.02

For train consisting of locomotive, tender, and freight cars, count number of cars in train; multiply this by .01; add to product .13; and multiply sum by the square of the velocity.

For train consisting of locomotive, tender, and passenger cars,

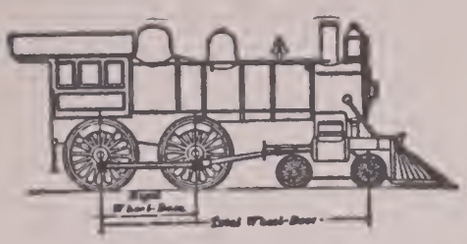
multiply number of cars in train by .02; add .13; multiply sum thus obtained, by the square of the velocity.

Another method of estimating the resistance offered, by still air to a train, either freight or passenger, is to ascertain the length of the entire train in feet; add 347; multiply sum by .0003; and multiply product by the square of the velocity.

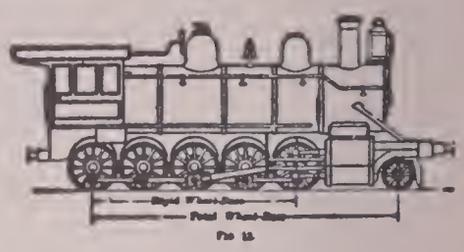
In making estimates of resistance according to above rules, it must be borne in mind that the air is supposed to be still, and the force of resistance is supposed to be exerted "head on" against front end of moving train. If the wind is blowing "head on" against the train, and the velocity of the wind can be ascertained; then *add* velocity of wind (in miles per hour) to velocity of train, and result will give relative velocity of train to air, which will be the factor to be used in the calculation. Thus, if train is running at 25 miles an hour dead against a wind of 30 miles an hour, the velocity of train to be used as a factor in calculation would be 25+30 (or 55) miles per hour.

If wind is blowing from rear exactly in direction of moving train, it is reasonable to assume that the relative velocity of train to air would be found by *subtracting* velocity of air from velocity of train. Thus, a train running 45 miles an hour with a wind in same direction of 30 miles an hour, would be moving only at a velocity of 45—30 (or 15) miles against the wind.

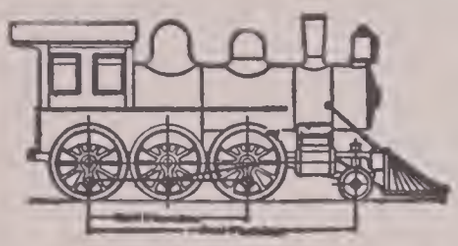
There are as yet no definite figures available for cases where wind at various velocities blows against side of train at different angles. The air resistance, in such cases, will vary with every difference in velocity and angle of the wind; and in making allowance for same, only rough approximate estimates can be made.



American, or Eight-Wheeled.

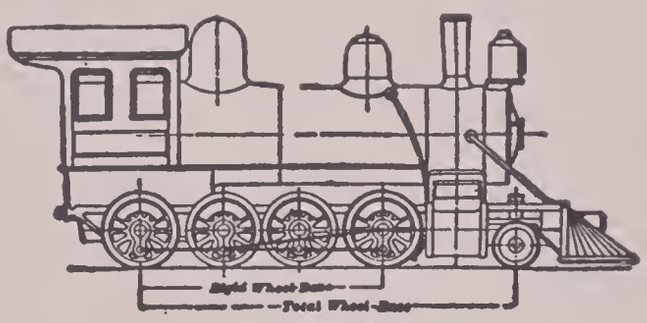


Decapod.

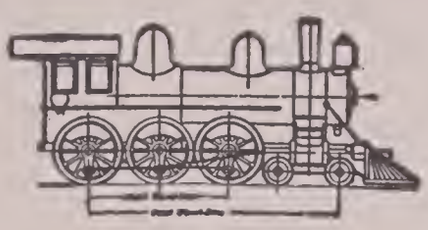


Mogul.

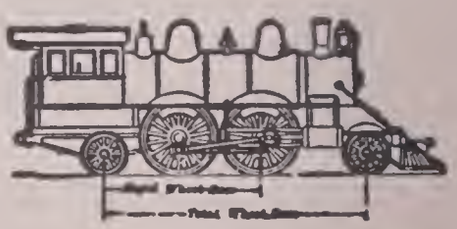
Atlantic.



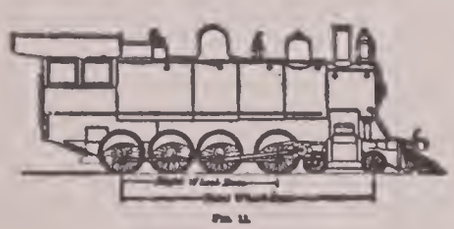
Consolidation.



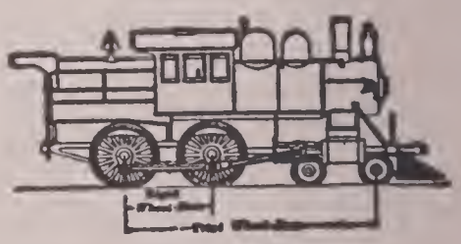
Ten-Wheeled.



Columbia



Twelve-Wheeled.



Wide Firebox.

SOME COMMON TYPES OF LOCOMOTIVES.

*POUNDS IN LOCOMOTIVES.

"Pounds are generally caused by slack wedges or rod keys, or a loose driving binder. A broken frame or driving box jaw will cause a pound, but quite often their breakage is due to a neglected pound in a rod or box.

"A loose follower bolt or head, a piston loose on piston rod, or a main rod keyed too long and allowing piston to strike cylinder head will cause a pound, and if very bad will result in the breakage of the cylinder head itself. A pound of this kind is more pronounced when steam is shut off and engine drifting, as all the slack in the rod and connections is free to move to the limit, there being no steam pressure in cylinder to cushion and restrain. A pound of this kind is more noticeable when main rod is passing forward center.

"If a pound is caused by a main rod being too long, have it shortened; if by a loose piston head or any of its parts, remove cylinder head and tighten the part.

"With a main rod long enough so that packing rings can drop into counter bore, and yet not long enough so that piston will strike cylinder head, the sound will be much the same as a pound and is rather more difficult to locate. The mark will show on the edge of the counter bore if cylinder head is taken off and an examination made.

"Little can be done for a pound caused by a broken frame or pedestal jaw except to work the engine lightly to the terminal and have the necessary repairs made there.

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*W. L. French.

"Pounds cause nuts to work loose and fall from bolts, binder studs to work out and be lost, and rod straps, pedestal jaws and frames to be broken.

"A bad pound at the front end of the main rod is more liable to cause a breakage of a strap than any other pound, as the whole strain is thrown on the strap when the rod is in tension. In keying the front end of a main rod care must be exercised not to get the brasses too tight on the wrist pin, as front end brasses cut out easily if too tight. Key on lower eighth or quarter. The wear is greatest on the front and rear of the wrist pin, owing to the direct pull and push of the piston. In keying, the key should be driven a little at a time and the front end of the rod moved laterally on the wrist pin with a short chisel until the desired tightness of the brass to the pin is secured.

"Owing to the peculiar motion of the front end of a main rod, which is a combination of the movement of the crosshead in the guides and the crank pin of the main driver to which the back end of the main rod is connected, the wear on a wrist pin is different than that to which the crank pins are subjected.

"The keying of back end of main rods seems to be a matter of opinion or individual experience as to the best position of the crank pin when key is driven. If a pin is round it makes not the slightest difference as to its position when key is driven, or even if the pin is out of round and the man driving the key knows how to key at the position the pin is in, for in the other positions the crank pin will assume in its revolution no bad effects will result.

"One large system desires that men being examined for promotion shall answer that they key back ends of

main rods on the center. Personally, I key a rod wherever it may chance the position of the pin is when I desire to key it, although I consider the quarter preferable, as a key driven so that the connection can be moved easily back and forth on the pin by the hands will not bind to do any harm or be loose enough to pound unless the pin is notably out of round; then, keying in any position will not obviate these troubles and nothing will except a new pin.

"The man who keys the back end of a rod so there will be a thump in it at all—with a pin that is much out of round—when the engine is given steam and thumped will have trouble. Naturally the thump will come where the pin is the smallest, and driving the brasses tight at that point will result in a hot pin.

"Where rod grease is used care should be taken to wait until the grease in the brasses is well worn out after screwing cup plugs down before keying rods, for if the brasses are full of rod grease they will not move freely on the pin and one gets the impression that the brasses are tight on the pin, when in fact they are not. In case one starts the babbitt in a brass it should all be thrown out before stopping. Babbitt is seldom thrown out where grease cups are used. A pin might become hot from brasses being too loose—that is pound hot. If a pin runs hot it is not advisable to slacken the rod key at that connection unless key has been recently driven and is too tight. Look for some other cause for the trouble.

"The side rods should be keyed on the center, as at that point the length of the rods will not be changed so as to interfere with the revolution of the crank pins. Side rod brasses will not pound, but will click if run too loose. If, on keying, a rod is found to be too short or

too long, the changing of a liner from the front to the back of the pin, or vice versa, as the case may require, will remedy the trouble. If the side rod is too short the outside brass will get the hottest; if the rod is too long, the end or outside brass will be the hottest. These troubles are not likely to occur unless rods have been down and not put up the proper length.

"The keying of a double-keyed middle connection of a ten-wheel engine should be in the following manner:

"Place engine on center and drive both keys clear out. Put one key in and drive it clear down, make a scratch on the key along the top of the strap and drive key out. Do the same with the other key. Start both keys and drive them down equally; that is, so that when brasses are keyed satisfactorily the lines on the keys will be equally distant from the top of the strap. The other ends of the side rods can then be keyed. Side rods are often put up with what are known as solid ends. Brass bushings are fitted into the enlarged ends of the rod. When put up they run very nicely, but as they wear, while they do not pound, they rattle and make a great deal of noise, and as there is no way of keying them up snug to the pin they are often allowed to run in this condition a long time before new bushings are substituted for the worn ones.

"Properly the wedges should be adjusted before rods are keyed, but on most any engine, except one recently from the shop or one that has been neglected, the wedges will be up and rods keyed, except as to ordinary wear one becoming loose requires them to receive attention. Under the pool system on most railroads the adjusting of wedges and, to a large extent, the keying of rods is left to the roundhouse force, and as a rule these things are not cared for as they should be.

"No one can adjust wedges and key rods as successfully as the man running the engine, as he has the opportunity to note anything that is needed and can apply the remedy, but with pooled engines it is not reasonable to expect engineers to do this work, and the roundhouse having assumed it, should look after it more closely than it usually does, for the heavy class of power soon pounds itself to pieces when neglected.

"A wedge should be so adjusted that the box can move up and down freely in the pedestal jaws without sticking and, at the same time, not allow room for the box to pound in the jaws. On smooth, well ballasted track this is not difficult to accomplish, but over very rough track wedges will have to be run a little slack or else the box will stick and the engine ride very hard.

"The engine should stand on level, straight track when wedges are being adjusted, as a curve in the track or an inequality in its surface will pinch the box and wedge together, or allow too much slack in the boxes on one side on a curve, and a proper adjustment can not be obtained. The wedge should be forced up as far as it will go and then pulled down a little, say from one-fourth to one-half inch, according to the track the engine runs over and the condition of the wedge. If the wedge is rough or has a shoulder worn on it, more play will be needed. Taking into consideration the gradual taper of the wedge it will be seen that pulling one down one-half inch does not give a very large amount of play to the box.

"Where wedges are set up by the roundhouse force, two pinch bars, one in front and one behind the wheel, may be used to pinch it up and down and show whether or not the box has the proper amount of up and down motion in the pedestal jaws.

"When it is desired to get all the slack in a box against the shoe before setting up the wedge run the wheel to the box with a pound against a block on the wedge side or the wheel at the opposite end of the journal against a block on the shoe side.

"After a wedge is set up it should be well oiled before starting out. If a wedge bolt breaks, block between the binder and bottom of the wedge and between the frame and top of the wedge. It may be held in place sometimes by putting washers on the binder and changing the set nut so that it will overlap the break, but blocking will usually be quicker and easier to accomplish.

"When a wedge sticks, loosen the set nut on top of the binder and tighten nuts under binder, or run wheel over a good sized nut; this will pull the wedge down. It may be necessary to cool box down before doing this. If in a hurry, oil the wedge and box good, loosen the set nut and go. This treatment ordinarily will result in the wedge being loosened and coming down without further trouble.

"Stuck wedges are not only hard on the engine, but also on the roadbed, and are particularly liable to do damage to bridges, and an engine should not be run any distance in that condition, and more particularly at a high rate of speed.

"Wedges need more oil in dry weather than in damp, as the dust dries up the oil on them the same as on guide bars or other parts of the machinery. The top quarter offers the best opportunity to work at wedges.

"A loose driving binder will cause a pound similar to a loose wedge, and may be caused by loose bolts or the binder being poorly fitted to the jaws. The hollow binder with a large bolt through it and the binder jaws

is preferable, as it is more easily kept tight than where the binder is fitted to the lower ends of the pedestal jaws and studs are used. These studs are continually working loose and getting lost, and causing extra work and expense to replace them."

LOCATING BLOWS.

It often occurs that when a locomotive engine has a pound, it is difficult for a young engineer to find the cause. To find the cause, an examination should be made of the connecting-rod brasses; if the brasses are not too loose on the pins the keys must not be driven to stop the pound, but proceed further to find the cause, by examining the driving-box brasses and driving-box wedges. Also, examine the set-screw that holds the back of the wedge against the pedestal, if it is too long it will press against the driving-box, and cause a pound. Proceed next to caliper the tires to see if they are all the same size. If one tire is softer than the rest, that tire will wear faster than the rest, and become smaller in diameter, and will have to slip every revolution. The difference between the circumference of that tire and the larger ones, will cause a pound; or, if one tire is harder than the rest, so as not to wear as fast as the other tires, it will cause a pound, the same as if it were smaller. There will be no difficulty in finding the cause of the engine pounding, if proceeding as above described.

The cylinder-cocks may be used when the valves or packing blow, to find out where the blow is located. When testing the valves, the reverse lever must be in the center notch, so that the engine will be in mid-gear, and the crank-pin vertical with the center of axle;

or, in other words, the position of crank must be at half-stroke, on the side of the engine to be examined. Next in order, set the tender brake, and admit steam in the steam chest, should the valve not be tight, or blow, as it is termed, the steam will come out of the cylinder-cocks. Should the face or flange of the valve be worn thin then the pressure may force the valve to be tight when not in motion. The blow, when the flanges are thin, trembles, caused by the vibration of the valve.

If the blow is in the packing, it can be detected by watching the cylinder-cocks. If the blow continues throughout the stroke, when working full-stroke, it will be in the packing. It may also be detected by the sound of exhaust, by watching the stroke of piston.

[THE USE OF TRAMS AND THROW OF AN ECCENTRIC.]

In response to questions asked by an engineman the following explanations relative to the use of trams and the throw of an eccentric were given by John Burns in the Firemen and Engineers' Magazine, which we reproduce by permission:

"Trams are used in almost every class of machinery, and wherever it is desired to know at all times if there has been any change in adjustment, or where it is desired to ascertain if rods are of proper length and valves set properly without removing steam-chest cover.

A piece of 3-16-inch steel is best for lengths from 3 inches to 6 inches, and for longer lengths ¼-inch or ⅜-inch steel may be used. All trams should be made of steel and their points hardened and ground, because there is less liability to tram bending when handled roughly or carelessly. In order to prevent any errors that might

arise from this cause, punch marks should be made on some stationary place convenient to get at, and space apart the exact length of tram. By inserting the legs of tram in the punch marks one can readily ascertain if its length has been altered in any manner.

We will take a case where the engineer is required to set the valves of an engine which he has been running. If he is prepared for such an emergency he will have two trams in some convenient place, easily accessible

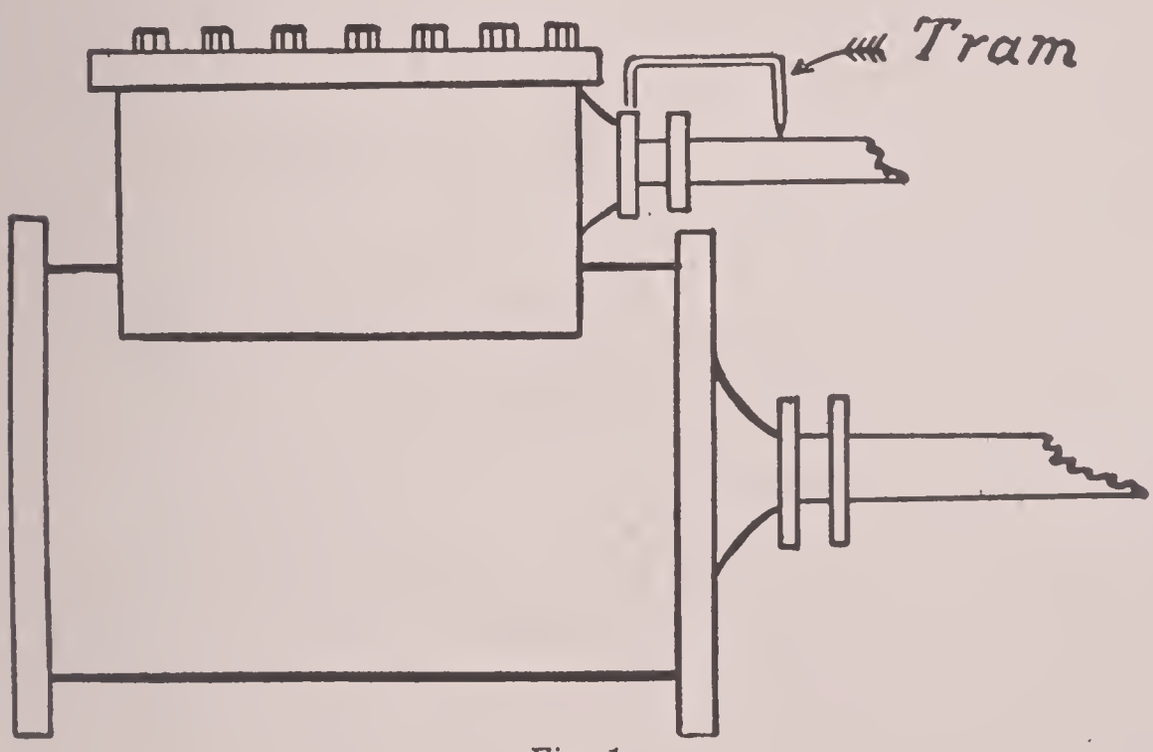


Fig. 1.

when in a hurry—a short tram of suitable length, say 6 inches, for setting the valves, and a longer one to be used in placing engine on dead center. The length of the latter will necessarily be 18 or 20 inches. We will suppose that the dead centers have been located and the position of valve properly marked with reference to dead center, for which it should open before engine has left the shop.

By placing engine on forward dead center and placing link in its proper position to that position of crank—that is, lowering link by moving reverse lever to extreme forward position—then, while holding one leg of tram in mark on stuffing box, not the gland, as shown in Fig. 1, and having the eccentric shifted or moved around on the shaft until the other leg of tram can be inserted in punch mark on valve rod, then if marks have been properly made and the length of tram has not been altered, the valve will be set for forward motion and this position

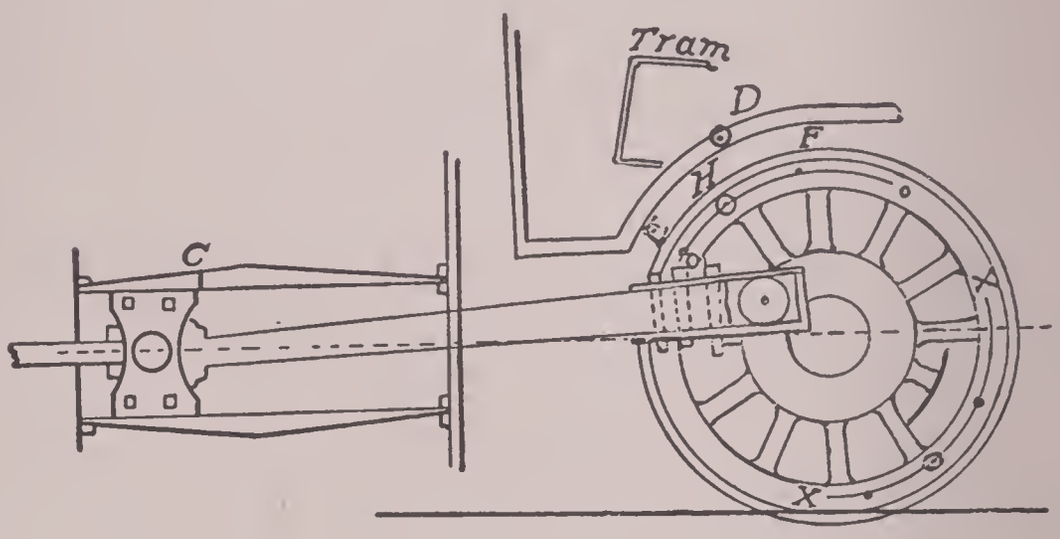


Fig. 2.

of crank. The same marks and tram may be used for either eccentric if the rod of the eccentric it is desired to set is brought in line with the valve, and crank is in proper position corresponding to this eccentric. The importance of having the crank on exact dead center when valves are to be set cannot be overestimated.

There are several different methods of placing crank on exact dead center. For instance, if engineer is running a stationary engine or locomotive, and the foundation or track is exactly level, then placing a spirit level

on the main rod and moving engine until the rod is exactly level is an approximate method. A better plan is shown in Fig. 2. The engine is moved to the position shown in sketch, although it makes no difference which dead center is secured first. This matter is left to the convenience of the engineer.

It will be noticed that the crank stands at an angle of about 15 degrees with the line of centers, and that the cross-head has not yet reached the end of its stroke. Now, procure a small piece of board or a square piece of one-inch material, the length of which should be two or three inches longer than the radius or distance from center of driving shaft to center of tire circumference. Drive a nail at one end, and, with the center of shaft

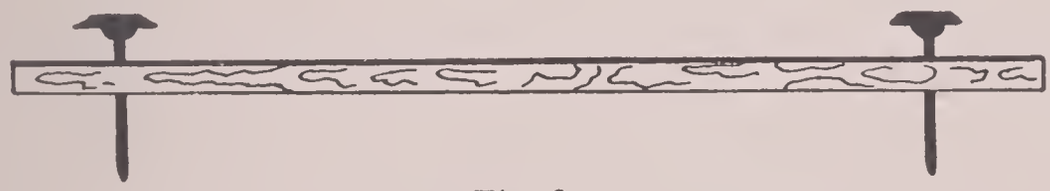


Fig. 3.

or axle as a center, estimate the distance to where other nail should be driven. Your improvised tram will now have the appearance of Fig. 3. Now insert one end of tram in center of shaft and scribe two arcs as shown at *oo* and *xx*. It might be claimed that by using a pair of dividers and with the circumference of the tire as a guide, one might secure the same results, but this method would not be as accurate. We now place a punch mark large and deep enough to be readily seen at a convenient stationary point near driving wheel. On most engines a point on the wheel cover will do, as shown at *D*. Then, with a tram of suitable length, say 15 inches, place one leg of tram in punch mark on wheel cover, and with the

other leg scribe an arc *E,* cutting the line made by the large tram. Now, with a straightedge and a sharp-pointed piece of steel wire, make a mark on the crank end of cross-head, as shown at *C;* now move the engine from this position with a crow-bar and the cross-head will have the point *C,* and when engine has passed the dead center the cross-head will again come to point *C.* Allow engine to stand in this position, and with the same tram and the punch mark at *D* as a center, scribe another arc cutting the line on periphery of wheel at *F,* then with a pair of dividers or a compass divide the distance from *E* to *F* in two equal parts and at the exact center place a punch mark; then with one leg of the 15-inch steel tram inserted in punch mark *D* on driving wheel, and have engine moved ahead until the other point of tram can be placed in the central punch mark *H.*

In order to distinguish this central mark from the others and avoid any errors in the future, it would be advisable to mark it. Take a cupped set screw and place the round cutting edge central over punch mark; a light blow with hammer will place a ring around the mark. Try the same performance at *D.* In the same manner move the engine near back dead center and scribe the arcs on line *xx* on circumference of tire, using the same method and marking guide at other end in same manner. The same tram and punch mark at *D* may be used. Should it become necessary in the future to set the valves the engineer may find either dead center by moving engine until the 15-inch tram can be inserted in the proper punch marks for the respective dead centers. Then with the tram for setting the valve, which may be of any convenient length, the valve may be set if the marks have been properly made.

Possibly some of the readers who have been through this experience on numerous occasions may think we have gone into detail more than is really necessary. In reply we would state that this letter was intended to reach those who do not know.

The writer has found it much more convenient to use trams to locate proper positions of valves and rods than to go over the whole performance of setting or readjusting valves, for the reason that in the latter case one must remove the steam chest cover.

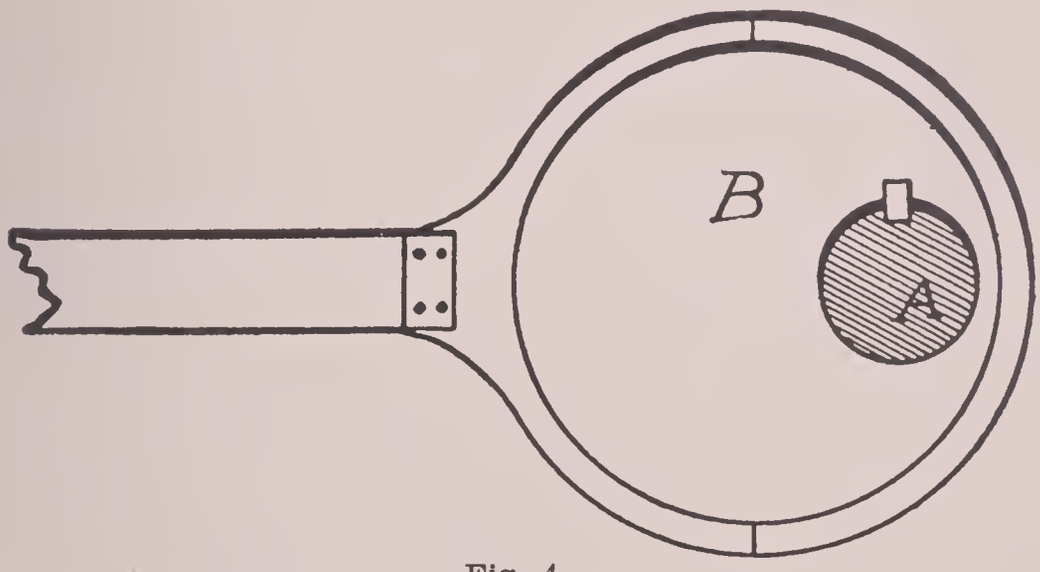


Fig. 4.

As a complete explanation of the valve setting can not be gone over in this letter, and answer the questions at the head of this letter, we will now define what is meant by the throw of an eccentric; question 2.

In some respects the mechanical engineers remind one of the medical profession. They may often clothe their ideas with language that is mysterious and hard to understand.

We must remember that the eccentric is a crank, and that it travels in its circle in the same manner as the

crank of the engine, and the distance from one side of this circle through the center to the other side is what is termed the throw of an eccentric.

Suppose we use the crank as an illustration. In the same manner that the travel of the crank in a horizontal distance, that is, the distance from one dead center to the other, is also the travel of the cross-head and piston, so the distance from the center of shaft to the center of the eccentric disk is the travel of the valve from its central position, and twice this distance is called the travel of the valve. In Fig. 4, *A* is the shaft and the outer circle *B* is the eccentric. The distance from the center of the shaft to the center of the eccentric is called the radius, and twice this distance is termed the "throw." It is obvious that this radius must equal the travel of the valve from its central position when eccentric rod is in line with the valve rod.

LOCOMOTIVE BREAKDOWNS.

What can be done toward preventing accidents and breakdowns?

Before starting and frequently during trips careful inspections should be made and at the end of each trip a thorough inspection of all running gear, frames, cylinders, saddles, bolts, wheels, fire-box, smoke arch, and all other parts of the locomotive should be made and all defects correctly and intelligently reported. The report should be explicit and a cause should be assigned for every failure. This aids the shop force in remedying defects. In reporting work on any wheel or truck on engine or tender the exact location and side should be given.

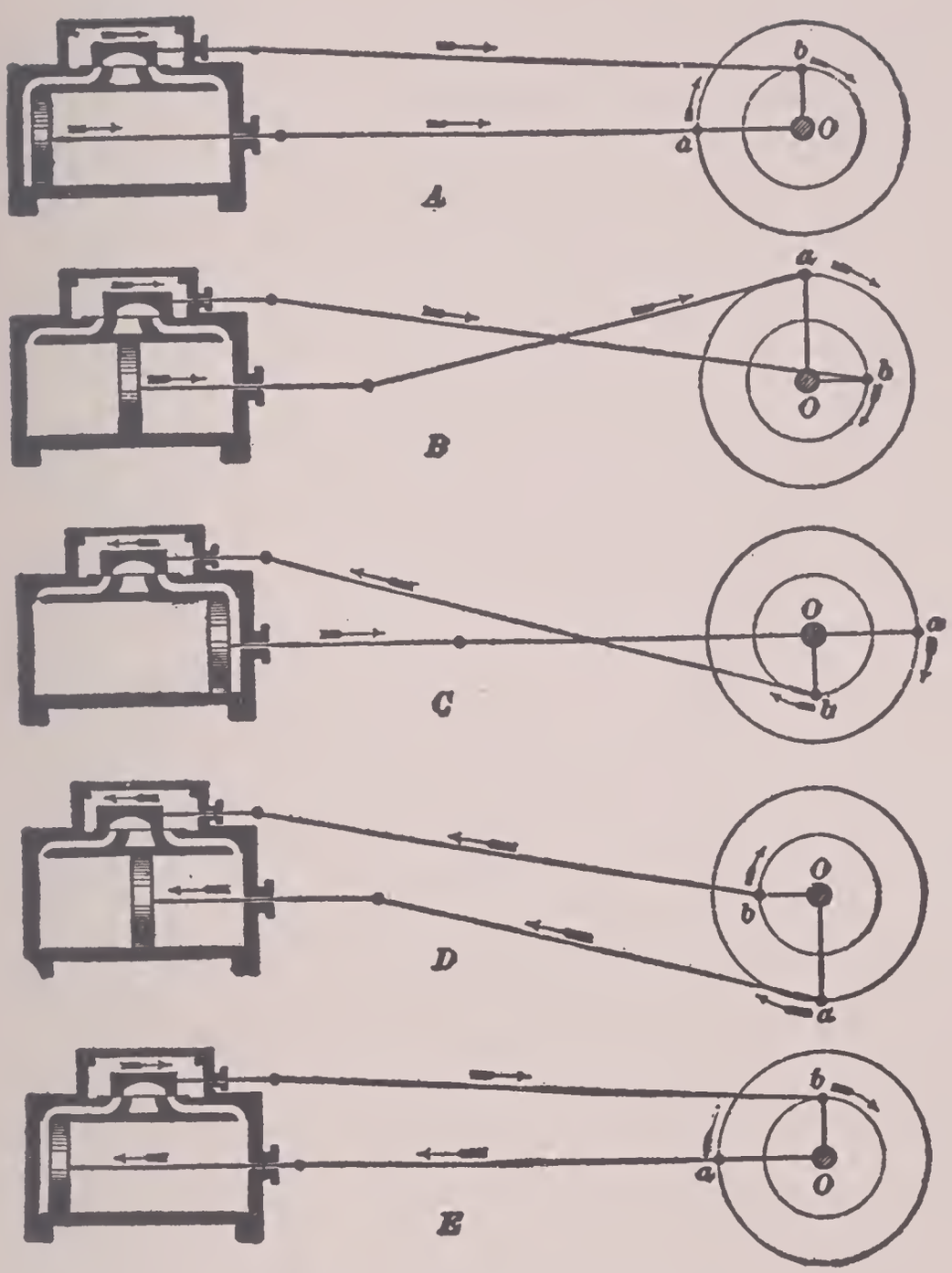


Diagram of Slide-Valve Engine.

Showing positions of piston, valve, piston-crank (Oa), and valve-crank (Ob) at each quarter-turn during one complete revolution of driver. At the start (A), port at left is about to admit steam, port at right about to be connected with exhaust, and piston about to begin outward stroke. All parts move in direction of arrows and have returned to original position in E.

What should be done immediately a locomotive becomes disabled while on a trip?

Protection should first be ensured by front and rear flags the prescribed distance. Temporary repairs should then be made as quickly as possible in order to proceed or get to the first siding. Every effort should be made to prevent blocking the traffic. Arrived at the siding repairs should be made with such tools as are at hand sufficient to allow of proceeding with safety.

When the breakdown is of a nature to prevent temporary repairs being made immediate steps should be taken to notify the nearest telegraph office of the location of the train, and full particulars should be given and assistance asked for.

"The prudent engineer who inspects his engine regularly and replaces the lost nuts, bolts and keys and tightens the loose ones, looks for defects and carefully examines any cracks or flaws or other defects upon his engine is seldom troubled with annoying and sometimes dangerous breakdowns while on the road," says T. A. Annis, in his reference book for enginemen; and he says, "An observant engineer who becomes familiar with the regular and equal exhausts of his engine often detects a lame exhaust in time to stop or prevent a serious accident to his engine, as any defect in the valve motion such as a loose eccentric strap bolt, loose blade bolt, a loose valve stem key, a broken valve yoke or slipped eccentric will cause an imperfect exhaust, but breakdowns sometimes occur after a man has done everything human foresight can aid in doing to prevent an accident."

*VALVES AND THEIR TROUBLES.

The series of questions and answers which precede the specific answers to questions by W. G. Wallace, upon the same general subject, contain valuable information. As they are arranged to lead up naturally to the subject of failures or breakdowns, it has been thought wise to give them in this volume, even at the risk of repetition in some instances.

Q. 1. Name the different types of steam valves used on locomotives?

A. The piston valve, the plain slide valve D-shaped, and the balanced valve.

Q. 2. Describe the plain slide valve.

A. The plain slide valve is a type of valve that is now but little used. It is D-shaped, the flat under surface of the valve working back and forth over a flat surface containing ports and called the valve seat. A yoke attached to the valve rod surrounds the valve body and controls its motion back and forth across the valve seat, thereby regulating the admission and exhaust of steam to and from the cylinders. The body of the valve is hollow and has lips projecting out from its base. The objection to this valve is that the top of the valve is subject to whatever pressure is admitted to the steam chest through the throttle valve, causing it to ride heavily on the seat, and requiring more lubrication than a balanced valve, and also lessening the effectiveness of the engine. The balanced valve was designed to overcome these defects, and it also permits of a more free handling of the reverse lever.

*W. L. French.

Q. 3. Describe the balanced valve.

A. There are two kinds, the balanced slide valve and the piston valve. The balanced slide valve is similar to the plain slide valve with this addition: Strips are fitted in the top of walled grooves around the top of the valves (a ring may be used instead of strips). In the bottom of these grooves arched flat springs are placed that crowd the strips against a plate fastened to the under side of the steam chest cover and called the pressure plate. These strips, when springs are in good order, prevent steam from passing in on top of valve, and makes it as nearly a balanced valve as can be made with this type. A hole is drilled in the top of the valve, so that any steam that might leak in on top of the valve past the strips can escape; otherwise pressure would accumulate and the balance feature of the valve would be destroyed.

Q. 4. Describe the piston valve.

A. It is the most perfect form of a balanced valve. It is a spool-shaped or cylinder-shaped valve, with packing rings in the ends to make it tight in valve casing walls. If the inside packing ring should become broken the end of the cylinder at that end of the valve would receive too much steam and the engine would sound lame.

Q. 5. Is the piston valve always cast in one solid piece?

A. No. Sometimes in two parts, held together by a rod.

Q. 6. What is the effect of the ends of the piston valve being near the ends of the cylinder?

A. The waste of steam due to clearance, which must be supplied each stroke, is lessened.

Q. 7. How is this saving largely lost in another direction?

A. On account of steam being around the end of the valve.

Q. 8. What was the piston valve designed to do?

A. To overcome all pressure and consequent friction in high-pressure engines, and lessen the amount of lubrication required. The wear on piston valves is not great under ordinary conditions.

Q. 9. Is it best when running down-hill to work a little steam with piston-valve engines?

A. Yes. It is best, for that matter, with any kind of valve, and the reverse lever should not be dropped into the corner, as the pull is very hard on the forward motion eccentric. After an engine has run down hill a short distance in the corner, pull the lever up several notches on the quadrant, and notice how much smoother the valves work. The jerking symptoms of the lever will be gone and excessive wear on the eccentric straps and danger of a hot eccentric will be largely avoided. The steam admitted to the cylinder serves two purposes, one as an aid to the lubrication of the valves and cylinders, the other to cushion the piston at the end of the stroke. If this is not done, the strain of stopping and starting the piston and its attendant parts twice every revolution of the driving wheels must fall entirely on the parts themselves, and is very injurious to them.

Q. 10. What is the by-pass valve?

A. It is merely a relief valve. It is used to guard against excessive cylinder pressure. The valve-chamber end of the valve is larger than the cylinder end. If the pressure in the cylinder becomes too great the valve opens and the excess pressure escapes into the valve chamber. A relief valve similar to a pop valve is used

on some engine cylinders to care for overpressure above what the cylinder is supposed to carry.

Q. 11. What is meant by inside and outside admission valves, as applied to piston valves?

A. Where the valve is surrounded by steam and the outside edges of the valve uncover the ports for the steam admission, it is termed an outside admission valve; but where the valve is hollow in the center, or spool-shaped, and the inside edges of the valve uncover the ports for the steam admission, it is termed an inside admission valve.

Q. 12. What is a direct motion valve gear?

A. It is one where the valve rod and the eccentric blade travel in the same direction.

Q. 13. What is an indirect motion valve gear?

A. One where the valve rod moves in the opposite direction to the eccentric blade. Most locomotives have indirect valve motion.

Q. 14. What is meant by the expression, "using steam expansively"?

A. After the valve in its travel has closed the steam admission port to the cylinder at such point as the position of the lever which controls the cut-off requires, the steam still continues to exert a pressure against the piston head, by reason of its elasticity and expansibility, with a lessening degree of pressure proportionate to the piston travel after the supply of steam is cut off from the cylinder.

Q. 15. What is cut-off?

A. The point where the admission of live steam to the cylinder is cut off by the travel of the valve. This point is arbitrarily fixed by the position of the reverse lever on the quadrant.

Q. 16. What is meant by exhaust?

A. The escape of the steam from the cylinder through the exhaust passages and smoke stack to the atmosphere after its work is done.

Q. 17. What is compression?

A. Any steam that might not escape by the exhaust would be confined in the cylinder and compressed by the return stroke of the piston, causing what is known as back pressure, and lessening the effectiveness of the engine.

Q. 18. What is meant by the lap of a valve?

A. Lap is the amount that the outside edges of the valve project over the edges of the ports when the valve is placed centrally on its seat. This is called outside lap. Inside lap is the amount that the inside edges of the valve project over the inner edges of the ports. Inside lap is sometimes called exhaust lap.

Q. 19. What is the result of too much inside lap?

A. Back steam pressure is caused in the cylinders, as the steam can not escape quickly enough to avoid the return of the piston.

Q. 20. On locomotives designed for fast trains where the steam must escape quickly, how is this overcome?

A. By giving the valve what is known as inside clearance. This allows the steam to escape earlier in the stroke. It is not an economical practice.

Q. 21. What is inside clearance?

A. The amount the exhaust port is open with the valve placed centrally on its seat.

Q. 22. Explain the difference in practice between inside lap and inside clearance?

A. Inside lap is to delay the escape of steam from the cylinders up to the point of back pressure, and is

desirable on engines not engaged in fast train service. Inside clearance is given to allow the quick escape of the steam from the cylinders, to avoid even a chance of back pressure, and is designed for locomotives in fast train service.

Q. 23. What is meant by placing a valve line and line?

A. So that the inside edge of the valve lines with the edge of the exhaust port.

Q. 24. What is lead?

A. Lead is the opening of the steam admission port when the piston is at the end of the stroke. If the engine is put up blind, or, in other words, with the port covered when the piston reaches the end of the stroke, there is nothing to cushion it in stopping, it is simply stopped by the strength of the parts. The lead admits steam just before the piston reaches the end of the stroke, so that it is checked easily and without great strain.

Q. 25. Has lead any other use?

A. Yes. It aids in carrying the engine past the dead points, or the points where the pressure against the piston-head is reversed. Otherwise the engine on one side of a locomotive must carry the other past the dead points. Lead also makes an engine smart, or quick to start, when given steam.

Q. 26. What lead is usually given to valves?

A. Freight engines one-eighth of an inch and passenger engines one-sixteenth of an inch. This lead increases as the lever is hooked up toward the center of the quadrant.

Q. 27. What is the cause of this increase of lead as the lever is hooked up?

A. The center of the driving axle, which the eccentric

cams surround, and the centers of the eccentrics are not a common center, owing to the fact that the holes in the eccentrics are not centrally placed, thus making of the eccentric one form of a crank, The radius of the link is taken from the center of the axle. The eccentric strap, that conveys by medium of the eccentric blade the motion of the eccentric to the link, has not the center of the axle for its center, but the center of the eccentric. The common center of the eccentric and the axle lies somewhere between their individual centers. Therefore, as the link is raised the eccentric cam crowds the link ahead, and opens the steam port more as the link is raised.

Q. 28. Why are freight engines given more lead than passenger engines?

A. Because they run slower and need more power to carry them past the dead points. Their cut-off is not so fine and they have better opportunity to rid themselves of their steam.

Q. 29. How is an engine given lead?

A. By advancing the throw of the eccentric from a right angle to the pin toward it enough to give the desired lead.

Q. 30. Can lead be given to valves by changing the length of the eccentric blades?

A. No. The exhaust can be divided so as to change the amount of steam admitted at either end of the cylinder, but the amount of lead will not be changed. If the port is given more opening by changing the blade the other one will be proportionally lessened. The valves are squared by moving the blades.

Q. 31. What is angular advance of an eccentric?

A. It is the amount the center of the eccentric is placed ahead of the center of the axle, and is equal to

the lap and lead. If angular advance was not given to an eccentric the piston would lead the valve. That is to say, it would have commenced its stroke before steam was admitted through the admission port to the cylinder.

Q. 32. What causes a valve to blow?

A. The valve or valve seat may be cut or worn so that steam passes between the face of the valve and the valve seat and blows through the exhaust port out of the stack. This can only be remedied by facing the valve and seat. A spring may become weak, or a strip broken, and cause a blow. A bridge between the exhaust or the admission ports might be broken or have a hole, or a valve might become cocked and cause a blow.

Q. 33. How would you test for a strip blow?

A. Put the crank pin on the side where the blow is judged to be, on the forward center, and the reverse lever in the center notch on the quadrant. Open cylinder cocks. Move the reverse lever forward a little, but not enough to open port, and open throttle slightly. If it is a strip broken or a weak spring, steam will enter the exhaust chamber of the valve and pass out of the rear cylinder cock. If the lever be moved slightly back of the center the steam will escape from the front cylinder cock. Care must be taken not to move the lever enough to open the ports. The steam coming from each cylinder cock alternately proves that the blow comes from above the valve and not under it. When a strip blows the valve and cylinder on that side will become dry, as the oil is blown away and wasted to a large extent.

Q. 34. How can a cracked bridge or a hole in one be located?

A. By examination, and the fact that these defects would only cause a blow at one end of the stroke. A

cracked valve or cut valve or seat will blow all the time.

Q. 35. What could be done in case of a cocked valve?

A. Jerk the lever back and forth. If this does not seat it, disconnect valve stem and move valve stem back and forth with a shaking motion. If this does not seat valve, take up steam chest cover and seat it.

Q. 36. How can a test be made for a piston packing blow?

A. Put engine so that side to be tested will have pin on top quarter. Give engine steam with brake set, and steam will blow out of both cylinder cocks if piston packing blows.

LAP AND CLEARANCE AFFECTING WORKING OF ENGINE WHEN EITHER IS CHANGED.*

Q. 37. "State the proper amount of lap and clearance for given dimensions of steam port and the effect of changing either the lap or clearance on the working or steaming of an engine?"

A. "All calculations for lap or clearance are, as a rule, based on conditions under which the engine is intended to operate and not on dimensions of steam port, and to a certain extent the dimensions of steam port are calculated from the same basis. The designing engineer or draftsman must first know the horsepower required and the speed desired; also the boiler pressure and whatever back pressure he will have to contend with. The maximum back pressure in a simple non-condensing engine is only that due to the friction of the exhaust steam in the exhaust pipes and nozzles, and the atmosphere which is unavoidable.

"It will be understood that the steam port area should be of such dimensions as to allow the steam to follow up the advancing piston without loss of pressure. In other words, the area of the steam port multiplied by the steam velocity in feet per second should equal the area of the piston multiplied by the piston speed in feet per second. Suppose we have a cylinder 16 inches in diameter, then the area would be $16 \times 16 \times .7854 = 201$ square inches. If the speed was 240 R. P. M. we would have $240 \div 60 = 4$

*Answer by John Burns.

revolutions per second, and our piston speed would be $4\times2\times3=24$ feet per second, assuming a stroke of 3 feet and the product of the area and speed would be $24\times201=4824$. According to one prominent engine builder, it has been found expedient to allow a steam velocity of 100 feet per second for slow speed engines and 125 feet per second for high speed engines. In this case we will use the factor of 125, then $4824\div125=38$, which equals our combined port area. This would give us 19 square inches for each steam port area, and its dimensions might be $1\frac{1}{2}\times12\frac{3}{4}$ inches.

"When designing a valve, the amount of lap given will depend on the point in stroke of piston at which cut-off should take place. Any of the methods explained by the different diagrams in text books will be sufficiently accurate. By the use of the diagrams one may find the required lap for a given stroke and valve travel. The following method has been used: From the length of stroke of piston subtract the distance piston will travel when cut-off takes place; divide the remainder by the stroke of the piston and extract the square root of the quotient; multiply this root by half the travel of the valve, and from the product subtract half the lead; the remainder will be the required lap.

"Assuming an engine with 30 inches stroke, cut-off $\frac{3}{4}$ of stroke with 5 inches valve travel; then using the above method $\frac{3}{4}$ of $30=22.5$, and $30-22.5=7.5$, which divided by $30=.25$, and the square root of $.25=.5$. One-half the valve travel is 2.5 inches, and $.5\times2.5=1.25$ inches. Suppose the lead to be 1-16 inch, then 1.25 inches — 1-16 inch = 1 3-16 inches, the lap of the valve.

"Another method of finding the lap of valve for a given cut-off with a given valve travel is shown by diagram in

Fig. 1. For this example we will suppose we are to design a valve for an engine with a 15-inch stroke, and that the cut-off is to be at ¾ of stroke. Our eccentric is designed to give a 3-inch valve travel. By this we understand that the distance from the center of shaft on

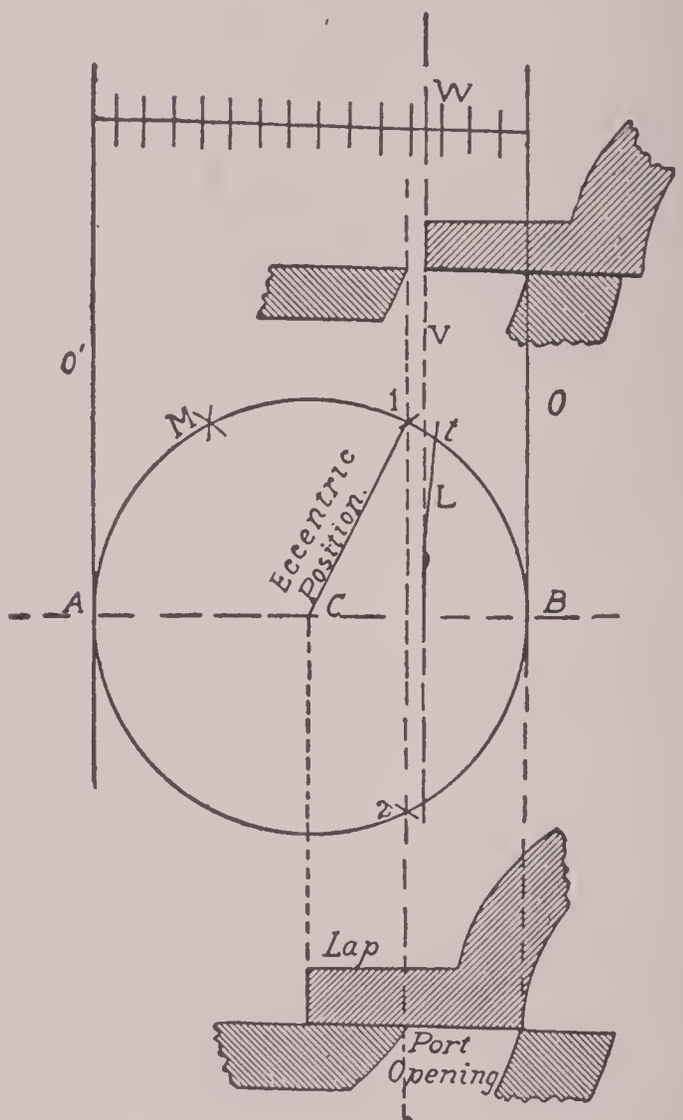


Fig. 1. Method of finding lap of valve for given cut-off and valve travel.

which eccentric is fastened to center of eccentric disk is 1½ inches, and that this center which corresponds to the travel of the crank will move in a circumference 3 inches in diameter. It can now be seen that our valve will travel 1½ inches either way from a central position

when moved by this eccentric. With a compass or divider, set to 1½ inches we draw a circle 3 inches in diameter, then with a rule draw the verticals *o' o* tangent to this circle; a horizontal line connecting these two lines can be divided to represent in inches the stroke of the piston, as shown at *W*. As we desire to cut off at ¾ of stroke, then ¾ of 15 inches is 11¼ inches; then from the point *W* draw the vertical line *V* parallel with the line *O*, and at the point where it meets the line *A B* will be where the piston is when cut-off takes place. The same measurements might be taken from the line *A B*, but in so small a space it could not be made as plain. Suppose that our main rod is three times the length of the stroke, then we draw an extension to the line *A B*, and with one leg of dividers in the point where cut-off takes place and the other leg on the extension of the line *A B* and with a radius of 9 inches draw the arc *L* and at the point where it intersects the circumference at *t* will be the position of crank when cut-off occurs. Now with the dividers set to this position of crank carefully divide the distance between the points *A* and *t* as shown at *M*, and with dividers set to same distance, and with point *B* as a center, draw the arcs *1* and *2*; at *1* will be the position of eccentric when crank is on dead center *A*, and *2* will be the position of eccentric when crank is at *t*. Now draw a line from *1* to *2* and the distance from point *B* to this line will be the port opening, and the distance from this line to the center *C* will be the required lap. It will be noticed that the amount of lead for this port area and piston travel is excessive. However, this was purposely done to show that the amount of lead given a valve will depend on the amount the eccentric is moved or pushed around on the shaft.

"If a plumb line were dropped through the center of the eccentric shaft and another line through the center of eccentric, then the distance between these two lines would give the distance valve had traveled from its central position.

"The effect of changing the clearance would be to increase steam consumption if clearance was enlarged, and engine would operate with greater economy as clearance was decreased. No better object lesson on the wastefulness of a large and unnecessary amount of clearance has ever come to our notice than was illustrated under the title of "Fads and Fancies" in the January issue of the Magazine. It is obvious that the volume of steam used to fill clearance space must all be released to the atmosphere, except the small amount which remains in cylinder when exhaust valve closes and which is compressed. It might be argued right here that this fact is convincing proof of the economy of compression, but it must be remembered we are using energy that has been stored in reciprocating parts of engine to compress this steam. The writer of this able article states that as a result of this error in the thickness of pistons in a run of 115 miles, 50,000,000 cubic inches of steam was wasted. Suppose we carry the calculation a little farther, 50,000,000 cubic inches = 28935 cubic feet and the weight of one cubic foot of steam at 135 pounds absolute, or 120 pounds gauge pressure is .305659 pound, and in the 115-mile run the fireman would shovel enough coal to evaporate $28935 \times .305659 = 8844.2$ pounds. Suppose we were evaporating 5 pounds of water per pound of coal, then we would burn $8844.2 \div 5 = 1768.8$ pounds coal more than necessary.

"It is plain that the volume of steam used to fill clear-

ance space must be released to the atmosphere when exhaust port opens, and when steam port again opens enough steam must be admitted to fill clearance space to sufficient pressure before piston will receive any impulse due to such pressure."

38. PRECAUTIONS NECESSARY WHEN VALVES ARE FACED, ETC.—"What precautions should be taken if any work or repairs have been done, such as valves faced, rod brasses filed, etc? "

Answer.—When the valves have been faced, the engine should be run a short distance with lever in full gear and lubricator feeding freely, before coupling to train. A little graphite introduced to the steam chests or valve seats if possible, will help to form a skin on the valves and seats and prevent cutting on the start. Use oil enough and as long a cut-off or valve travel as is possible for the first few miles. If there are no stops or drifting places, close the throttle for an instant and drop lever in full gear occasionally. Oil that may possibly be held in the oil pipes will thus be allowed to get down into the steam chests and on the valve seats. When the seats are smoothed up, cut the lubricator feeds down to regular supply. To get best results always use dry steam. If brasses have been filed on main rods, they must be properly keyed and the set-screws tight, back ends free on pins when on center, and front ends free when on quarter. If side rods, have them free when passing centers. Keep bearings properly lubricated and no trouble should be experienced.

39. VALVES BECOME DRY.—"When valves get dry when using steam and lubricator is working all right, what would you do to relieve conditions and how may you know that the valves are dry?"

Answer.—You will know that the valves are dry when the engine begins to lag with the train by the sound of the exhaust and the rattle or pull on the reverse lever. If the lubricator is working all right it is evident that the oil is not reaching the steam chests but is held up in the oil pipe, due to the steam chest pressure being greater than the pressure at the lubricator end of the pipe. This is called the hold-up of oil in the oil pipe. To relieve conditions, close or partly close the throttle for a revolution or two and place the lever at full stroke. If you can not shut off for this length of time partly close the throttle and drop lever into full gear. This will reduce the steam-chest pressure so that the pressure in the lubricator will be the greater and the oil will be forced to the valves and cylinders.

40. Broken Safety Valve Spring.—"What could be done if a safety valve spring should break?"

Answer.—Remove the cap, if there is one, on the pop and screw down the adjusting screw as far as it will go. If the jamb nut prevents the screw from going down far enough, split the nut and screw it down far enough to hold the valve solid to its seat. This broken pop valve spring will render the valve inoperative, but the others will relieve the pressure until you arrive at a terminal. This is one reason why two or more valves are used.

41. Locating Broken Valve Spring.—"In testing for a broken valve spring, how could it be located?"

Answer.—We will presume that you refer to the broken spring that holds the balance strip up to the pressure plate on the steam chest cover, or what is known as a valve strip blow. These springs hold the strips up to the plate and relieve the back of the valve from steam-chest pressure when they are tight. Any leakage past

the strip will escape into the exhaust passage through the hole in the back of the valve. The first indication of the broken spring will be a blow when the throttle is open, similar to that caused by the blower being on. This is caused by the steam passing by the strip and through the hole in the valve to the exhaust passage nozzle and stack. To determine which side it is on, place the engine on the quarter, open the throttle sufficient to produce the blow, then move the reverse lever from full forward to full back motion. If the lever can be handled easily, place the other side on the quarter and repeat the above. The side that the engine is standing on quarter when the reverse lever is hardest to move is the side that the spring is broken, as that valve has the greatest pressure on it holding it to its seat, and is the cause of the lever being harder to handle. The engine is placed on the quarter when testing each side to get full travel of the valve when the lever is moved from forward to back motion.

42. Locating Valve for Broken Balance Strip or Spring.—"What is the best method of locating the valve when a balance strip or spring is broken in an engine with a single nozzle and no drip ports drilled into the exhaust passages in cylinder saddle, and why should the spring or strip broken cause the valve to handle so much harder than the ordinary slide valve without the balance feature, and require so much more oil and then not handle as easy? If we break a spring or strip in these small engines, it seems as if the engine would break something before getting to terminal."

Answer.—To locate which side the strip or spring is broken on an engine as above described, place engine on quarter, open throttle, and give engine steam enough to produce a good blow at cylinder cocks. Then close

cylinder cocks and move lever from full gear forward to full gear backward motion. This will give you full travel of the valve on that side, and if it moves easy you will know that side is all right and that the valve has its usual balance. Then place engine on the quarter on the other side and repeat the operation. If the lever is harder to move forward and back with the throttle opened the same, you may safely report the valve that is hardest to move the lever when that side is on quarter or at half stroke. Another method is to get out on the running-board when engine is working slow and take hold of the valve rod, and you can easily determine which one has the broken strip or spring. The reason that a valve with a broken strip or spring requires more oil is due to the oil being blown from the chest past the defective strip through the hole in the back of the valve into the exhaust cavity, instead of going to the valve seat and lubricating it and the face of the valve. This causes the valve and seat to become dry and increases the resistance and makes the lever handle hard, and with a broken strip the steam chest pressure exerting a downward pressure on the back of the valve also increases the resistance. When the strips are all right they protect the inclosed area on the back of the valve from this pressure, but when they are defective the area of the back of the valve inclosed by the strip is exposed to the pressure without any relief only the amount of steam that escapes through the hole in the back of the valve. This amount of steam causes a blow similar to the steam from the blower, and is noticeable when the throttle is open. If you could get the surface of the valve and seat lubricated with a broken strip as well as you get the plain slide valve lubricated, a valve with a broken strip of the same

area and pressure would not handle harder than the plain slide valve.

43. Broken Piston Valve.—"I wish to ask how to get at it to bring in a piston-valve engine with a piston valve on one side broken and nothing to do it with, only the tool equipment that is necessary to get an engine over the road."

Answer.—First get the good side on the eighth or quarter so you can start engine when you get ready to go. Then disconnect valve rod from rocker arm, and if you can place the valve in position desired over the ports and secure it there, handle the case the same as you would a broken slide-valve engine, leaving the back port slightly open about the thickness of a piece of tin, and remove the valve from the back cylinder cock; this to prevent taking down the main rod. If you can clamp the valve rod in this position and it will hold the valve in place, steam will be admitted to the cylinder and will take oil with it to lubricate the cylinder while running in with main rod up, and if you at any time get stuck on the center on the good side, by replacing the valve in the cylinder cock steam will be admitted to the back end of the cylinder on the disabled side to move engine off the center on the good side and save pinching. If the valve is broken so that you can not do this you will have to take off the valve-chamber head and place the broken pieces so they will cover the ports, block them securely and replace the head. If the valve is so badly broken that this can not be done, the only way out of the difficulty will be to remove the broken valve entirely from the valve chamber and cut a piece of post or telegraph pole to fit the valve chamber, blocking the admission of steam to the cylinder and preventing it from escaping through

the exhaust ports to the stack. Get into the section house if you can not get the saw and axe out of the caboose, or borrow the tools from a farmer if near one.

44. Broken Steam and Exhaust Rings with Inside Admission Piston Valves.—"On engines having inside admission piston valves, what would be the effect if a piece of the steam ring on one end should break out? What would be the effect if an exhaust ring on one end should break?"

Answer.—With a piston valve the inside and outside edges of the valve rings are considered the same as the steam and exhaust edges of the slide valve. If the steam or inside ring of an inside admission piston valve was broken steam would be admitted to the port at that end of the cylinder too soon and would flow into that end of the cylinder during a longer period of the stroke, i. e., the broken ring in that end of the valve would not cut off the steam or close the port as soon as it should if the ring is all right. Therefore, it would admit the steam too soon and cut it off too late. The effect would be that too much steam would be admitted to that end of the cylinder. If the exhaust ring in the piston valve was broken steam from that end of the cylinder would escape to the exhaust port too soon, and in each of these cases the engine would sound lame. If the inside or admission rings are broken you can easily locate it by placing the valve central and opening the throttle and cylinder cocks. If an exhaust ring, note that the exhaust takes place too early. Many a piston-valve engine has had her valves run over when reported lame and the marks indicated that the valve gear and eccentrics were all right, and the trouble afterwards was found to be in broken rings in the piston valve. Try to

locate the broken ring. Better take a chance on having the rings examined than to report "Run the valves over" when the valve gear indicates no spring, broken or slipped parts.

45. TYPES OF PISTON VALVES.—"Explain the principal difference in the two radically different types of piston valves."

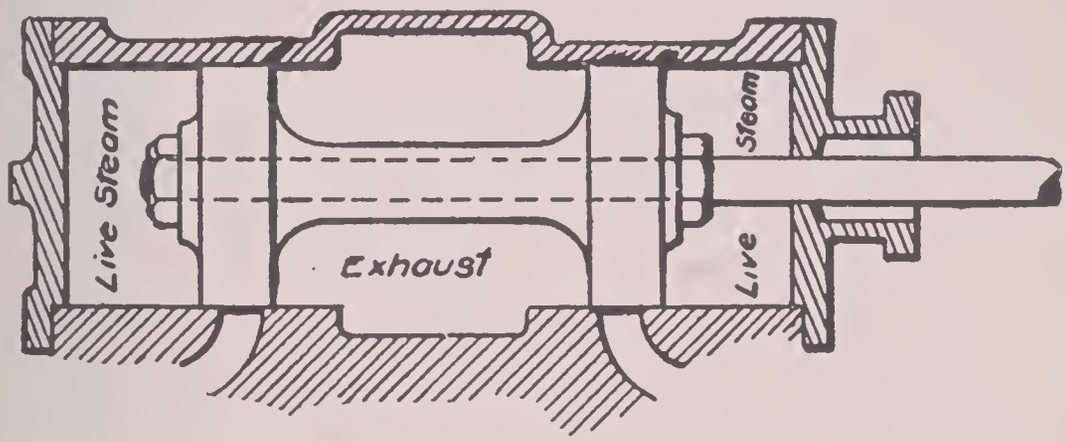


Fig. 1. Solid Piston Valve without rings, and outside admission.

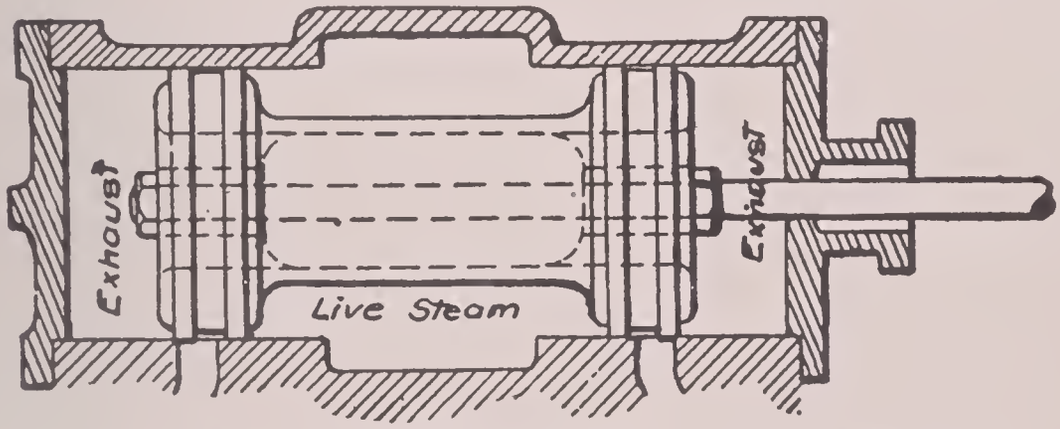


Fig. 2. Hollow Piston Valve, with rings in ends of spool, and internal admission.

Answer.—There are several kinds of piston valves used on simple engines. One is the solid valve without rings, and with outside admission, as in Fig. 1, and the other is the hollow piston valve with rings in the ends of the spool, as shown in Fig. 2, and internal admission. Note that the internal admission valve admits steam from the inside of the spool, and the outside admission valve ad-

mits steam from the outside ends of the valve when port is opened.

46. By-Pass and Main Piston Valves.—"How would you tell a broken by-pass valve from the main piston valve?"

Answer.—To distinguish between broken piston valve and defective by-pass valve, would place engine on quarter on defective side, and if by moving reverse lever steam could be prevented from blowing into exhaust port, would conclude that there was nothing wrong with the valve. In this case the reverse lever would be at or very near center of quadrant, this depending upon whether or not the valve had exhaust clearance.

47. Broken By-Pass Valve.—"If you broke a by-pass valve on a high-pressure cylinder what would you do? What if on a low-pressure side?"

Answer.—Take off the valve body and insert a blind gasket between it and the cylinder.

48. Blocking Crosshead in Disconnecting.—"Why is it necessary to block the crosshead in disconnecting? Why couldn't you, and wouldn't it be easier to, leave one port open a little and let a little steam in one end to hold piston to end of cylinder?"

Answer.—The reason a crosshead is blocked is to prevent further damage to the engine, and, if the style of engine will permit, it should always be blocked at the back end of the guides, although some engines require that they be blocked forward so that the crank pin will clear crosshead. It is much more up to date not to disconnect the main rod, but to leave it up wherever possible. First, get the engine on the quarter on the good side so you can start when ready. Then disconnect the valve rod on the disabled side and move the valve until a very little

steam is seen escaping from the front cylinder cock. Clamp valve rod, take out front cylinder cock valve and open the feed on the lubricator on disabled side so it will feed a little faster than on the working side, and you are ready to go. The opening of the port need not be any more than the thickness of tin or Russia iron, and in case you stop in the center on the good side you can move the valve on the disabled side to admit steam to get the engine off the center. If you have to run a long distance shut off, oil may be admitted to the cylinder through the oil pipe at lubricator, or through air inlet valves on the steam chest.

49. Testing for Broken By-Pass Valve.—"If a by-pass valve was broken, how would you test for it?"

Answer.—The piston valve can not raise from its seat to relieve the pressure in the cylinder when the valve has covered the port, hence the necessity of a means of relieving the pressure. The by-pass valve is placed between the live-steam chamber and the admission port, and located in a case that is bolted to the cylinder casting. When steam is admitted into the steam chamber between the pistons of a piston valve, if inside admission type, the by-pass valve is held to its seat by the pressure in the steam chamber. But when the pressure in the cylinder is greater than that in the steam chamber, the by-pass valve is raised from its seat and permits the steam to flow from the cylinder into the steam chamber, relieving the pressure in the cylinder in this manner instead of allowing it to escape to the atmosphere, as it would if a relief valve was used on the cylinder head.

To test for a broken by-pass valve, place the rocker arm plumb. This should cover the ports. Then open the cylinder cocks and the throttle. Steam will flow

past the broken valve and out of the cylinder cock at the end of the cylinder the broken by-pass valve is on. If blow will prevent your handling train properly to terinal, take off by-pass valve case and insert blind gasket between by-pass valve case and cylinder casting. In some cases you may be able to block the valve in position by removing cap.

50. Clamping Valve, with Main Rod and Piston Working.—"When clamping a valve with one port slightly open to lubricate cylinder in case where the main rod is left up and piston allowed to move in the cylinder, would you advise taking out cylinder cock in opposite end from the end where port is left open, or in other words, would you advise both cylinder cocks taken out? I have seen instructions to take out cylinder cock in the end that the port is left open, but it seems to me that when the piston moves towards the open port it would go against atmospheric and steam pressure and the partial vacuum at the other end of he cylinder causing a great resistance. Wherever both cocks were removed the vacuum would be less. How much would you leave the port open, judging from the flow of steam from the cylinder cock? How much resistance would the piston work against, and is there any danger of cutting the cylinder? Would you feed oil any faster on the disabled side?"

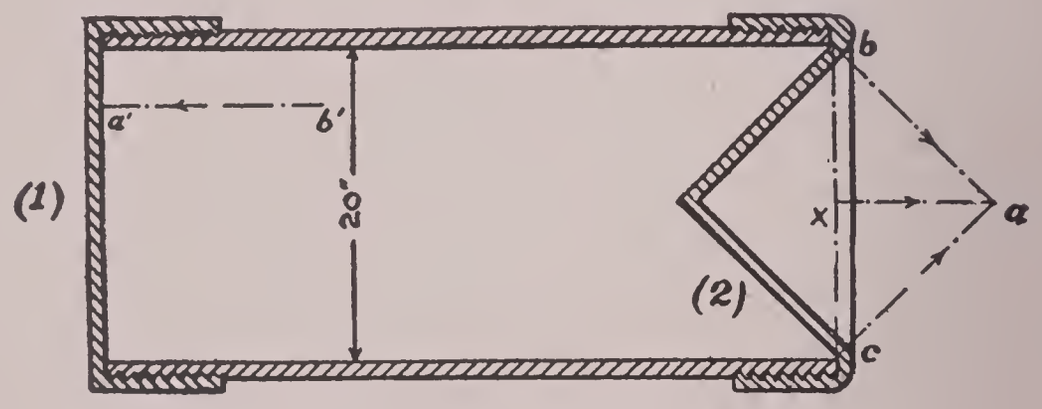
Answer.—Take out the cylinder cock at the end of the cylinder that you left the port open. The port opening need not be more than the thickness of a piece of tin. Judging from the steam escaping, move the valve until you get steam to show at cylinder cock so it can be seen two or three feet away from the cock. All you want is just enough steam to keep the cylinder from cutting and to carry the oil into the cylinder. To do this, feed the oil

a little faster on the disabled side than on the working side, and when running, shut off; oil may be admitted through the oil pipe at lubricator or through the air inlet valve on steam chest. It is not necessary to take out the other cylinder cock. As to the resistance and vacuum on each side of the piston, it would all depend on the speed and condition of the cylinder packing rings. There is no danger of cutting cylinder if engine is properly handled. However, you will be responsible for consequential damage, but if you follow instructions you will be safe in handling the engine in the above manner.

51. Effect of Changing Length of Eccentric Rods.—"I notice in your answer to Question: 'What effect would changing the length of the eccentric rods have on the lap and lead of the valve?' you say that lead would be affected by changing the length of these rods, but the lap would not be changed. Now, we read in many of our mechanical books that lead is the amount of port opening at the beginning of the stroke, and is brought about only by the angular advance of the eccentric on the shaft; that lap is the part of the valve that extends over the steam port when the valve is in middle position; that it delays admission and enables us to secure an early cut-off. Now, your answer admits that lead is secured not only by the angular advance, but also by the changing of length of the eccentric rods, a point with which I fully agree, but it is not clear to me why the lap is not also changed, as is not admission delayed and cut-off hastened at one end? For an example: Suppose the go-ahead eccentric rod on an indirect valve motion outside admission was lengthened, this would shorten the forward travel of the valve and lengthen the backward travel, measuring from a line drawn through

the center of the exhaust port, and now the center line of travel has been moved back an amount equal to the change of the length of the eccentric rod, both rocker arms being same length, and such change would cause steam to appear too early at the front end of the cylinder and too late at the back end, and the cut-off would be late at the front end and early at the back end. Now, would this not be virtually increasing the lead at one end and the lap at the other?"

Answer.—According to the answer to Question, you are correct in stating that the lap is changed as well as the lead when the eccentric rod is lengthened or shortened, or that lead would be increased on one end and lap at the other. The answer states that the lap of the valve is a fixed amount and never varies, and changing the length of the eccentric rod would have no effect on it; that is true. Now, the lead is obtained by advancing the eccentric toward the pin from an angle of 90 degrees.



Pipe with Flat and Cone-shaped Caps.

52. Pressure on Flat and Cone-shaped Surfaces.—"If I take a piece of pipe, any length or size, and screw an ordinary cap on each end, my argument with a friend was that if one of them was a flat surface inside and the other was cone-shaped, as per sketch, the

pressure would be considerably less on the cone-shaped end with any given pressure inside the pipe than it would on the other end, which had a flat surface inside. I claim that the pressure will follow the angularity of the surface given to pressure. Please state the difference in pressures, and oblige?"

Answer.—There would be no difference in the pressure exerted on each cap, tending to force them from the pipe or to strip the threads, as the pressure is equal.

This brings to mind a valve that was made with a back to it like the angle shown by the fine lines at the cone-shaped cap, in order to reduce the pressure on the back of the valve, but it was found that the pressure on the valve seat was the same as on the valve with the flat back. Theoretically, we will take the above cut for an example and let the diameter of the cylinder or pipe be 20 inches, drawn to a scale of 1 inch equals 1 foot. Let the interval pressure be 14.15 pounds per square inch tending to force the caps from the pipe or cylinder, represented by a line *a b* drawn to a scale of 12 pounds to the inch, or 1 pound per inch of scale of the drawing. Then the pressure on cap (1) equals the area of a 20-inch circle multiplied by 14.15, which equals 4,445 pounds. Let cap (2) be a 45° cone. Then the area of the cone will equal 444.5 square inches. Now the effective pressure on this area tending to remove the cap must be one-half the resultant of two forces, each equal to *a b,* acting perpendicular to the surface of the cone, or at right angles to each other, as *a b* and *a c,* which equals the sine of the angle of 45° multiplied by 14.15 pounds equals 10 pounds. Then 444.5 (area of cone in square inches) multiplied by 10 pounds equals 4,445 pounds, same as on cap (1). There is no difference.

53. Friction of Valve and Slip of Link.—"Why is it that when an engine is working hard the lever pulls toward the corner of the quadrant for three exhausts and toward the center with one exhaust? I have noticed on any engine that I have been on that there is one exhaust which, if you catch just right, the lever hooks up easily, and the other three you can hardly pull the lever back. We have three 20x26-inch cylinder engines that are almost impossible to hook up unless you get them just right. We do not have piston valves, but I understand they are not affected that way. Will you please explain?"

Answer.—The reason that the lever pulls forward for three exhausts and back on one exhaust is due to the friction of the valve and the slip of the link on the link block. The valve moving hard over its seat at slow speed and a well opened throttle cause increased friction between the link and the link block. If the pull on the lever was constant in the forward direction the lever would not rattle when the valves got dry. As it is, the pull is forward while making three-quarters of a revolution, or for three exhausts, and backward for one exhaust. Get out on the running board and note that the tumbling shaft arms lift up when left side is passing back center running ahead, and pulling forward while passing top quarter forward center and bottom quarter left side. Tightening up or placing more tension on the counterbalance spring and more efficient lubrication on valves will partially overcome this trouble. The reason that this is not as noticeable on piston-valve engines is due to the fact that a piston valve is more perfectly balanced than a slide valve.

54. Covering Ports When Engine Having Lead is on Center.—"Can the ports of an engine having lead be covered by the valve when the engine is on center?"

Answer.—If the valves are set with lead in both forward and back motions the ports could not be covered on the side that is on center, as lead is the amount of opening of the steam port when the piston is at the beginning of its stroke, and the lead is increased as the lever is notched toward the center. With both motions set with lead it would be impossible to cover the ports when on center, as the lead would be the same with lever in either forward or back motion and would increase as the lever was drawn to the center of the quadrant.

55. Valve Travel with Lap and Lead.—"Will the valves of an engine having lap and lead travel when the reverse lever is in the center notch of the quadrant and the engine is drifting? If they will travel, why and how much?"

Answer.—A valve will always travel twice the lap and twice the port opening, whatever the cut-off may be, and many locomotives have a valve travel that is greater than twice the lap and the width of the steam port, but they never have less. To illustrate the answer to this question, we will take an engine with 5-inch valve travel and eccentrics 5-inch throw, 1-inch outside lap set with 1-32 inch lead opening in full gear both motions. In the 6-inch cut-off, the lead would be increased to 3-16-inch with a maximum port opening of 5-16 inch. We would have a valve traveling 5 inches at full gear, but when working in the 6-inch cut-off would only travel twice the lap, which is 1 inch and twice the port opening, which in this case is 5-16-inch, or a total travel in this notch of 2⅝ inches. Therefore, it is clear that the valve will travel twice the lap and port opening, whatever it may be, and, as the lead increases as the lever is notched up toward the middle gear, it can be easily figured from the marks on

the valve rod. Why do the valves travel? Because the motion is imparted to the link arm of the rocker by the eccentric strap and rod. When the eccentric rod is in line with the link block, or nearly so, that eccentric controls the action of the valve. But when the link is raised to mid-gear, both eccentrics control the action of the valve, and the travel is decreased as the link is raised from full gear to center. Figure that the back motion eccentric coupled to the lower end of the link is the fulcrum, the link block the weight, and the forward motion eccentric the power or force to move the lever, which in this case is the link, and you have the explanation as to why the valves travel and how much in any position in which the reverse lever may be placed.

56. Effect of Decreased Valve Travel.—"What is the effect on an engine if the travel of valve is decreased?"

Answer.—The effect of shortening the travel of the valve is to increase the lead, both steam and exhaust, and decrease the port opening for the admission of steam to the cylinder, which produces an earlier cut-off and increases the expansion. This causes a reduction in the port opening for the exhaust steam to escape from the cylinder and increases the compression.

57. Travel of Valve When Steam Lap and Port Opening is Known.—"When the steam lap and port opening are known, what must be the travel of the valve?"

Answer.—If the valve is to open the steam port its full width, the travel of the valve must be twice the width of the steam port and the lap of the valve.

Example: Width of steam port, 1¼ inches; lap of valve, 1 inch. 1¼+1=2¼ inches, and 2¼×2= 4½ inches. Answer, 4½ inches.

If the valve has over-travel—that is, if it travels over the edge of the bridge—you can take one-half the width of the bridge multiplied by 2 and add to the above. You will then have a valve travel equal to the width of the steam port plus the lap plus one-half the width of the bridge multiplied by 2.

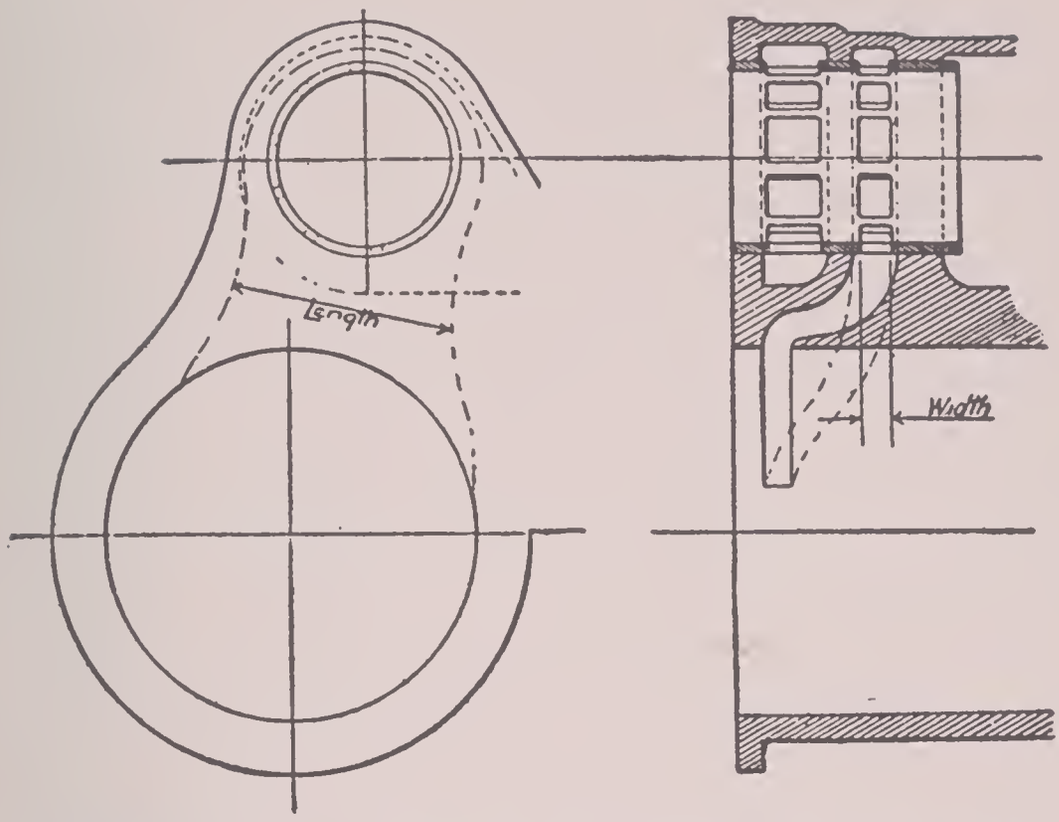
58. Relation Between Valve and Link.—"Will you kindly explain the relation between the valve and the link? Does the valve travel as far when the lever is hooked up as in full stroke? How is the supply of steam cut off? Some claim it is cut off in the exhaust cavity."

Answer.—The forward motion eccentric is connected to the top of the link and the back motion eccentric to the bottom of the link, and the eccentrics are set on the axle in position to admit steam to the cylinders and cause the engine to move in either direction. The link block being connected to the lower rocker arm remains stationary in respect to the rocker, but the link can be raised or lowered by the reverse lever, tumbling shaft, link hangers, etc. Now, when the lever is in full gear, either in forward or back motion, the eccentric rod is opposite the link block and moves with the eccentric rod. The movement given the rocker is transmitted to the valve. This gives full travel of the valve with the lever in full gear, and steam is admitted during the stroke of the piston. The travel of the valve to open the steam port fully cannot be less than twice the width of the steam ports and twice the lap of the valve. If we had an engine with steam ports 1⅝ inches and lap on the valve of ⅞ inch, to get full port opening we would have to give the valve a travel of $(1\frac{5}{8}+\frac{7}{8})\times 2=5$ inches, but most locomotives have a slight overtravel. The supply of steam is cut off by the valve closing the port when the piston is at a cer-

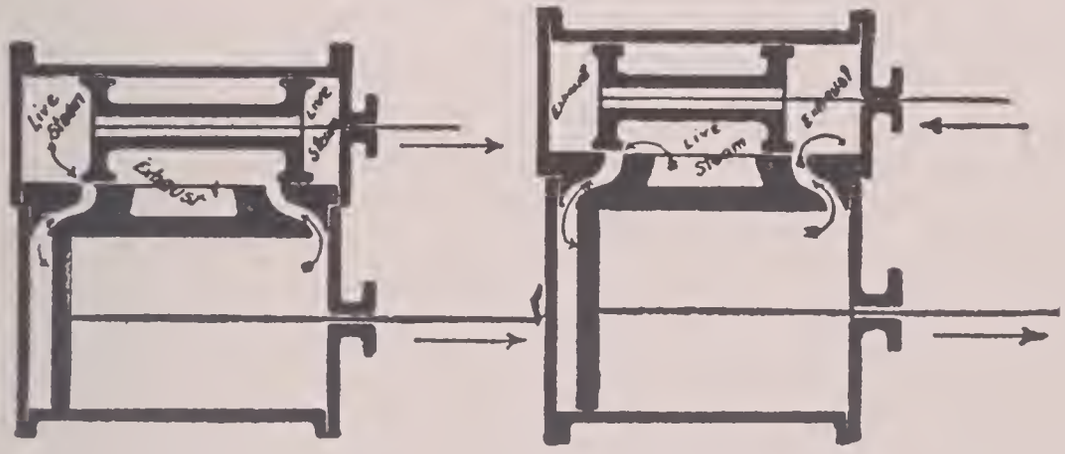
tain portion of its stroke. In that event the port is not fully opened. We will say that steam was cut off by the valve closing the port when the piston had moved 7 inches of the stroke and we would have a maximum port opening of ¼ inch; of course the lever would be hooked up to give this cut-off and we would have a valve travel of port opening plus the lap of the valve×2=2¼ inches. When the lever was hooked up it raised the link on the link block nearer the center of the link, and instead of the forward motion eccentric imparting its motion to the rocker arm it received its motion from both eccentrics or a compound motion which decreased the travel of the valve. The outside edge of the steam ports and the edge of the valve cut off the admission, but the inside edge of the steam port and the edge of the exhaust cavity of the valve cut off the exhaust.

59. Dimensions of Ports in Piston-Valve Engines.—"How do you get the dimensions of the ports in a piston-valve engine?"

Answer.—The accompanying sketch shows an end and part of a side view of a piston-valve chamber, bushing and cylinder. In speaking of the width of the ports they are measured for width the same as in the slide valve. Taking the width of the full lines shown in the bushing as the width, the dotted lines show where the chamber is cored out to allow the steam to flow into the port leading to the cylinder. The bridges in the bushing are to keep the rings in the piston valve from entering the ports when the valve passes over them and the width of the port openings in the bushings. To get the length of the port, measure the shortest distance between the valve chamber and the cylinder, as shown in the sketch. This will give the width and length of ports.



End and partial side view of Piston-Valve Chamber, Bushing and Cylinder.



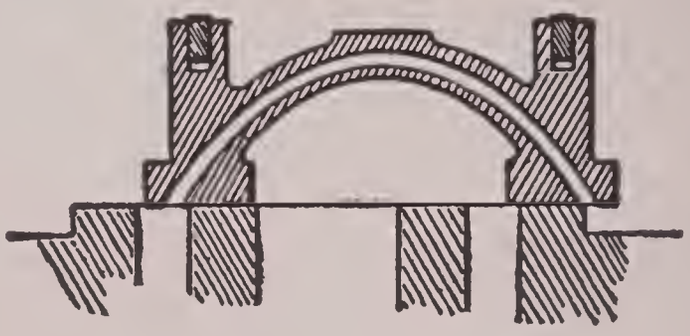
Outside Admission Valve. Inside Admission Valve.

60. Relative Motion of Main Piston and Valve for Inside and Outside Admission Valve.—"What is relative motion of main piston and valve for inside admission valve and outside admission valve?"

Answer.—The answer to this question is herewith illustrated. The arrows indicate the motion of valve and

piston in each case. Note that with the outside admission the valve moves in the same direction as the piston while opening the port for admission, and with the inside admission the valve moves in the opposite direction to the piston while opening the port for admission.

61. THE ALLEN PORTED VALVE.—"Describe an Allen ported valve and the advantage claimed for same."



Answer.—An Allen ported valve is similar to the plain "D" valve, but it has a supplementary steam port or passage above the exhaust cavity; see illustration. Its advantages are to admit steam to the same cylinder steam port from both sides of the valve at the same time which will permit a smaller amount of lead opening than by the "D" valve. The Allen valve will give twice as much opening for the admission of steam at a short cut-off as the ordinary valve, and is very desirable for high speed service. It opens the steam port at admission and closes it at exhaust at twice the rate of the "D" valve.

62. BALANCE SLIDE VALVE.—"What is a balance slide valve, how is it balanced and why?"

Answer.—A balance slide valve is a valve provided with strips or rings that surround a portion of the area of the back of the valve to relieve it of pressure, and these strips or rings form a steam tight joint between the

part of the valve and the underside of the steam-chest cover. Note the plain "D" slide valve in sketch, Fig. 1. You have steam-chest pressure forcing the valve to its seat at all times when the throttle is open, and the exhaust steam and the steam pressure in the cylinder when the valve has just closed the steam port or cut-off the steam forcing it up from its seat. The area of the valve being the same on both top and bottom of the valve and the steam-chest pressure being the greater, friction is produced that absorbs power. To reduce the friction and lessen the power required to move the valve back and

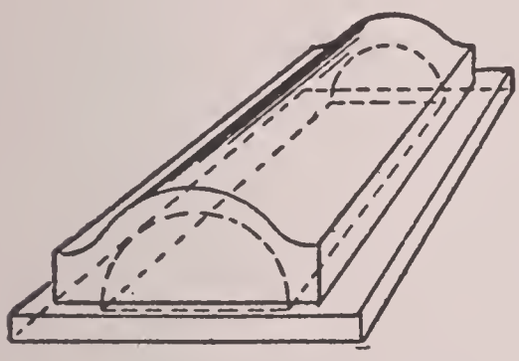


Fig. 1. Plain "D" Side Valve.

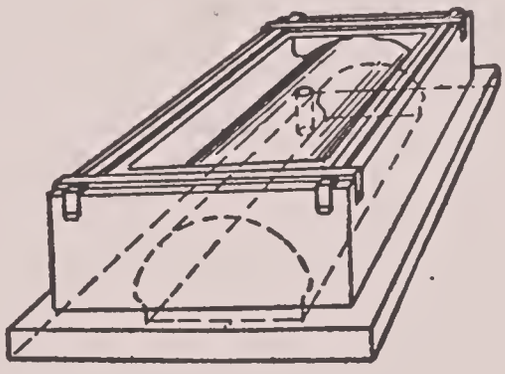


Fig. 2. Balance Valve.

forth over its seat for the admission and exhaust of the steam to and from the cylinder, strips or rings are employed to keep the pressure from a certain portion of the back of the valve, as shown in sketch, Fig. 2, and a hole or holes are made in the back of the valve to allow any leakage of steam past the strips or rings to escape to the exhaust cavity, thus relieving this part of the valve from steam-chest pressure. The valves are balanced to increase the efficiency of the engine, reduce the cost of lubrication, and to make the engine easy to handle.

63. Length of Cylinder.—"I noticed that when the bushing was removed from the cylinder of a 20x26-inch

engine, the bushing was 34 inches long. Now, I would like to know why this engine was called a 20x26-inch cylinder engine, when the cylinder is 34 inches long?"

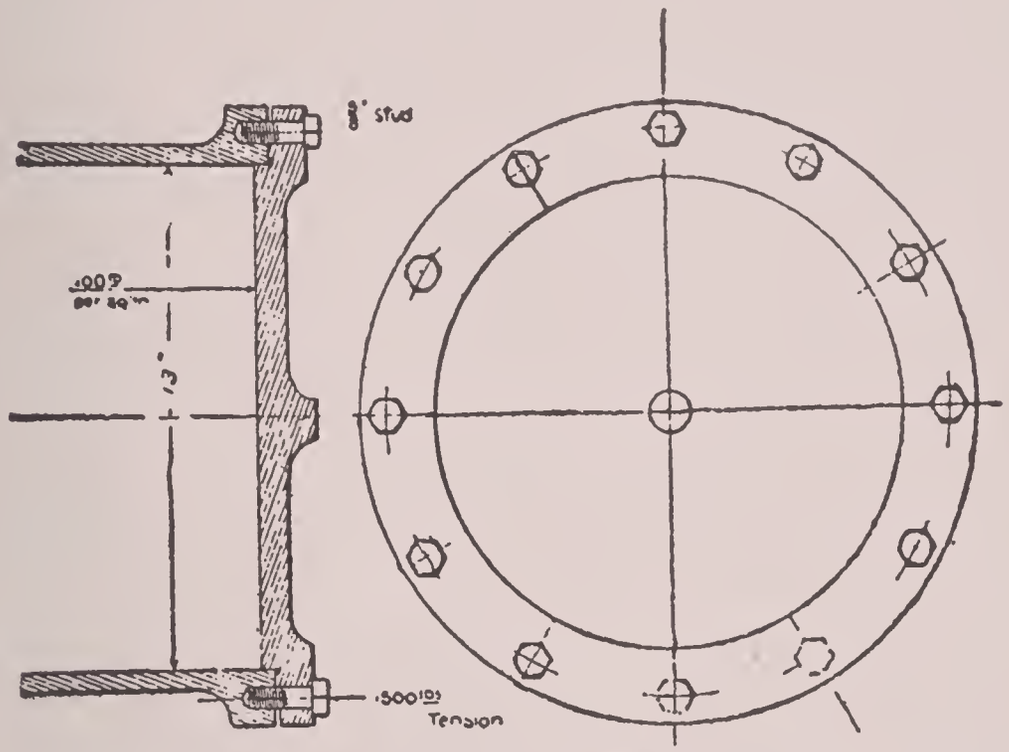
Answer.—The length of the cylinder is usually stated as the stroke of the piston, although the real length of the cylinder is the distance between the cylinder heads. This engine having a 26-inch stroke, possibly had a piston head 5 or 5¼ inches thick, with at least ¼-inch clearance at each end of the stroke, or a total clearance of ½ inch, and the front and back heads extend into the cylinder, to take up the balance of the space between the ends of the bushing. It is correct to term this engine as a 20x26-inch cylinder.

The writer was recently very much interested to observe several enginemen trying to determine the length of the cylinder on some heavy engines that were going over the road, by taking measurements outside of the cylinder casings; the proper method would have been to measure the distance from the center of the axle to the center of the crank pin and multiply this by two, which would have given the correct length of stroke.

64. Stress on Cylinder Head Studs.—"Suppose we tighten the twelve nuts on a 13-inch cylinder head until we have, for instance, 1,500 pound stress on each stud holding the cylinder head to the cylinder, and then we admit steam to the cylinder to the amount of 100 pounds per square inch, is there any additional stress on the studs?"

Answer.—In this case we would have 12 times 1,500 pounds, which would equal a stress of 18,000 pounds strain holding the head to the cylinder. The area of a 13-inch cylinder is 132.73 inches, and 100 pounds pressure would equal 13,273 pounds, or 4,727 pounds less than

the pressure of studs on the head. By dividing 18,000 pounds by the area of the cylinder in inches we find that the pressure on the steam side would have to exceed 135.7 pounds per square inch before there would be additional strain on the studs. (See illustration.)



1,500x12=18,000 pounds pressure holding head against cylinder.
Area, 13 inches circumference=132.73 square inches.
132.73x100=13,273 pounds steam pressure against head.

65. CYLINDER CLEARANCE AND BLOCKING.—"With the kind of a guide yoke which bolts on top of the top guide and under the lower guide, there is nothing at the back end to prevent the piston coming so far back as to allow the packing rings to get caught in the counterbore. How would you block to prevent the piston coming too far back?"

Answer.—An engine that would allow the packing rings to get caught in the counterbore of the cylinder would have excessive cylinder clearance. All the room there is between the piston and the cylinder head when

the piston is at the end of the stroke is called "cylinder clearance." In blocking the crosshead at either end of the stroke you would have the thickness of the piston or follower up the groove for the packing ring, and then have almost the width of the ring additional to move back or ahead before the ring would get caught in the counterbore, which rarely, if ever, occurs. Even if it should, no damage would result, as it would be discovered when repairs were being made. So block her clear back and get ready to go in on one side.

66. Cylinder Packing Blowing.—"Where does the cylinder packing blow the most—at the beginning of the stroke, on the eighth, or on the quarter?"

Answer.—Some kinds of cylinder packing will blow the most at the beginning of the stroke, because the steam has not set it out against the cylinder walls until the stroke has commenced. If the cylinder is round and not cut or scored and of the same diameter through its entire length, and the guides properly lined to keep the piston running true in the cylinder, the greatest blow should be from the admission line to the point of stroke where the steam is cut off, and then as the steam expands in volume the pressure would be reduced and the blow would become less. It is the usual practice to place an engine on the quarter or half stroke with lever in full gear to test the packing blows on that side, but both sides may be tested at one time by moving the engine in position that both crossheads are opposite each other or of equal distance from the back end of guides or back cylinder heads. Placing the engine as above, the packing on both sides and both ends of the cylinders may be tested in two positions.

67. Engine Drifting with Reverse Lever in Center of Quadrant.—"While engine is drifting with

reverse lever in the center notch of the quadrant, do the rocker arms stand perfectly still, or do they move forward and back a small amount? Explain in detail."

Answer.—You understand that the lead is increased as the lever is hooked up toward the center of the quadrant. Lead is the opening of the steam port when the piston is at the beginning of its stroke. Now, in order to get any opening of the steam port, the valve must first travel a distance equal to the lap. Therefore the valve and rocker arm would have to travel a distance of twice the lap plus twice the lead with lever in center notch while drifting.

68. Kerosene for Cleaning Cylinders and Valves. —"Is it good to give an engine kerosene into the relief valves when drifting, for cleaning out cylinders and valves?"

Answer.—If balance strips are stuck in the valve, or a packing ring gummed up in the piston, a slushing of kerosene oil will sometimes loosen them up, but it should be immediately followed by a liberal allowance of valve oil. A solution of lye would do equally as well as kerosene for this purpose, but would not recommend either. Good dry steam and valve oil are the best things to put in a cylinder or steam chest. If graphite is used, feed it in with the oil or water, but do not use a low grade of oil in your steam-chests or cylinders, as it burns and causes trouble and does not lubricate at high temperature. Keeping the throttle cracked sufficiently open to hold the relief valve shut when drifting, and the use of dry steam and valve oil, will obviate the necessity of using anything else in the steam-chests and cylinders.

69. Blows in Main Valve and Cylinder Packing.—"How can a blow in the main valve be located and how can a blow in cylinder packing be determined?"

Answer.—Place the engine on the center, on the side you wish to test. Plumb the rocker arm and this will place the valve central on its seat. Open cylinder cocks and throttle. If steam blows out of one or both cylinder cocks when the valve is covering the ports, it indicates that the valve is blowing. In case you find that the valve is tight and you want to test the cylinder packing, place the lever in full gear, either forward or back. This will open either the front or back port leading to the cylinder; close the cylinder cocks and block open the cylinder cock at the end of the cylinder opposite to the end where the port is open, set the brake and pen the throttle, and if steam blows out of the open cylinder cock, the cylinder packing on that side will, as a rule, be found to be leaking. The sound of the steam escaping through the exhaust nozzle and stack will also assist in locating a cylinder packing blow. Taking off the front cylinder head and admitting steam to the back of the cylinder is a dead sure way to locate a cylinder packing blow.

70. PORTS NOT COVERED BY VALVE.—"Can the ports of an engine having lead be covered with the valve when the engine is on dead center?"

Answer.—Lead is the amount of opening of the steam port when the piston is at the beginning of its stroke. Lap is the amount of the valve that extends over the outside edges of the steam ports when the valve is in the center of its seat. If your engine had neither lap nor lead, the eccentrics would be set at right angles to the pin, but as you have both you advance the eccentric toward the pin to pull the valve back the amount of lap, then advance it still farther to give the lead opening desired. Looking at the side of the engine that is on the dead forward center it can be readily seen that if the en-

gine has lead when the lever is in full gear forward, pulling the lever back on the quadrant will push the lower end of the rocker arm ahead and the upper rocker arm back in proportion to the radius of the link or, in other words, increase the lead as you hook the lever back until midgear when it decreases as the lever is moved from mid-gear to full back motion and if the engine has lead in both motions, forward and back, the ports could not be covered on that side without disconnecting the valve rod. However, if the valves were set with lead in one motion and blind in the other, the ports could be covered by the lever in the motion that was set blind but not in the motion that had lead. Place the engine on the right forward dead center, mark the valve stem with the lever in full gear forward, then have the lever moved from full forward to full back motion and watch the marks on the stem as the lever is being moved. If set with the same lead for both motions you can see that it would be impossible to cover the ports.

VALVE GEAR AND ITS TROUBLES.

Question 1. What can be done to repair an engine with a broken valve seat?

Answer. It depends on the manner of the breakage. If a front port was broken, place the valve so as to cover the back steam port and the exhaust port. Disconnect and clamp valve stem. Take down main rod and block crosshead. The reason for taking down the main rod is that, steam having free admission to the front end of the cylinder, the engine on that side would be working against itself one-half of the time. For a broken back port place the valve over the front steam port and the exhaust port and proceed as for a broken front steam port. Usually a broken valve seat will cause other damage to valve gear, as broken or bent rocker arms, eccentric blades, or valve rods. These parts should be carefully examined before proceeding to move engine.

In case a bridge is broken between a steam port and the exhaust port, cover ports with valve, disconnect valve rod and clamp it. Leave main rod up. Make certain that no pieces of the bridge have gone by any chance into the cylinder.

Q. 2. What is to be done in case of a broken valve?

A. Take up steam chest cover. Lay broken parts of valve together to cover valve seat. If too badly broken, use a block in place of the valve. Replace steam chest cover, and fasten it down. It will be necessary to use a block in place of the valve also if it is a balanced valve. If a piece of tin or sheet iron is available use it on top of valve seat.

Q. 3. What is to be done in case of a broken steam chest wall or cover?

A. If only a crack in the wall, take off steam chest casing. Loosen nuts to studs adjacent to the crack, and wedge between studs and wall of steam chest. Tighten nuts and replace casing.

If chest or cover is badly broken steam must be shut out from the chest. This can be done by inserting a blind gasket in the joint in steam pipe in front end. If this can not be done, block over steam ways in chest seat and hold in place with chest cover. A piece of sheet iron or tin under the block is a good thing. In going into front end to put in a blind gasket, have fire as low as possible and lubricator and air pump shut off. It is better, as a rule, to prepare engine to be towed to terminal.

Q. 4. How can a broken valve yoke be located?

A. When a valve yoke breaks, the valve will remain in front end of steam chest. Move lever back and forth with cylinder cocks open. If yoke is broken, steam will not come from forward cylinder cock.

Q. 5. How can repairs be made?

A. Take out relief valve cage. If necessary shift valve by means of a small bar inserted where relief valve cage was taken out, and move engine off center on good side. Then move valve to cover ports. Disconnect and clamp valve stem with inside end against valve. Put a plug against valve through relief valve cage hole and screw in cage to hold plug in position.

If the valve yoke is only cracked, drop the lever down and work a light throttle. It will probably hold until a terminal is reached. Engine will be lame on that side.

Q. 6. If a valve rod breaks outside of steam chest, what is to be done?

A. Cover ports and clamp valve rod.

Q. 7. If a cylinder head or piston head breaks, what is to be done?

A. Disconnect valve stem. Cover ports and clamp valve stem.

Q. 8. Should a main rod ordinarily be taken down?

A. No. Not unless damage to it or connecting parts render it necessary.

Q. 9. Is there any way to avoid stopping an engine—that is, on one side—on the center on the uninjured side?

A. Yes. Release brake and reverse engine, opening the throttle just before coming to a stop, and good side will be on the quarter.

Q. 10. What causes cylinder heads to break?

A. In the case of a front head, a broken rod strap, wrist pin, crosshead key, or a loose follower bolt. A broken main pin might break either head, or anything in the guides might break the back head. Weakness of metal is always a cause for failure.

With a broken front head, cover ports and disconnect and clamp valve stem. If head is only cracked it may be braced by a block from head to pilot beam, so that it will hold until a terminal is reached where repairs are made.

With a broken back head, cover ports and disconnect and clamp valve stem. Guides and main rod must come down, and piston be taken out of cylinder or fastened securely.

Q. 11. Where should a crosshead be blocked?

A. At the rear of the guides. Less damage would then result if it got loose.

Q. 12. What can be done in case of a broken valve stem or piston gland, or studs to glands broken?

A. With metallic packing, disconnect, cover ports and clamp valve stem.

Q. 13. What is to be done in case of a broken top or bottom rocker arm, or link block pin?

A. With top rocker arm, cover ports, disconnect and clamp valve with a lower rocker arm or link-block pin, cover ports, disconnect and clamp valve stem. Push top rocker arm back and fasten it so that lower arm will clear links in case of broken link-block pin. In covering ports the front one can be left slightly open to help lubricate the cylinder, and the lubricator can be fed freely on that side. If engine has indicator plugs in cylinder take them out and oil cylinder through these openings. If necessary the cylinder head can be removed and the cylinder oiled that way, as main rods are too heavy to take down unless absolutely necessary.

Q. 14. What can be done in case of a broken link hanger, saddle pin, tumbling shaft, or tumbling shaft arm?

A. Put a block on top of link block to work engine about half stroke, and a short block under link block, allowing room for slip of link. With broken tumbling shaft it will be necessary to block both links. Remove broken parts. To reverse engine, shift blocks from bottom to top of links. If one side only is disabled, good side can be reversed with lever. If an important train is being pulled, some waste could be put on top of link and engine could then go on at a reduced rate of speed.

Q. 15. How can a broken reach rod or reach-rod arm be repaired?

A. Block on top of link block with a block long enough to hold links at desired point of valve cut-off, with a short block under link block with space enough between block and link block to allow for slip of link. Only one

link should be blocked with this type of breakdown to allow for one link slipping up as the other slips down; should both links be blocked, damage will result to tumbling shafts. Blocks can be changed to reverse engine. A bar or a small timber can be laid on top of frame and under lifting arms to link hangers instead of blocking link.

Q. 16. What is the position of the eccentrics on the axle?

A. The throw of the eccentrics is at a right angle, less the lead, to the pin. The throw follows the pin.

Q. 17. How would you locate a slipper eccentric?

A. By the sound of the exhaust and by the position of the eccentrics on the axle.

Q. 18. What causes eccentrics to slip?

A. Becoming hot, loose, set screws and dry valves. This latter may cause a broken eccentric or cam bolt, just as a hot eccentric may cause a broken strap.

Q. 19. What causes hot eccentrics?

A. Oil hole stopped up, no packing in oil cellar, plug gone out of bottom of eccentric strap, a strap lined too tight, or one so loose as to admit dirt freely between strap and eccentric.

Q. 20. How should hot eccentrics be treated?

A. Open oil hole if stopped up. Oil freely and often with valve oil. If the strap has recently been closed it may be too tight, in which case a thin liner in the strap jaw will help out. Do not put water on a hot eccentric.

Q. 21. How would the exhaust sound with a slipped eccentric-strap blade or a loose eccentric-strap bolt?

A. Out of square, or the engine would go lame the same as with a slipped eccentric. When an engine goes suddenly lame do not drop the lever down. It may only be a dry valve, but it may be something else. If it is

something else, the sudden change in the travel of the valve when the lever is dropped down will break something.

Q. 22. How would you put a slipped eccentric blade back to its proper position?

A. Usually there will be a break in the grease and dirt where the blade enters the strap, to show where the blade should go. If not, put engine on forward center on side that has slipped blade. Open cylinder cocks and the throttle lightly. Throw the reverse lever back and forth, and note that if forward blade is slipped back little or no steam comes out of front cylinder cock, and if blade is slipped ahead it will blow strong out of front cylinder cock. Reverse the lever and just the opposite condition will prevail. If there is too much admission at forward end of cylinder, shorten the blade; if too little, lengthen it. The same procedure may be gone through with for the other motion eccentric.

Q. 23. How can a slipped eccentric be set?

A. Put engine on forward center on disabled side. Suppose that right forward eccentric is slipped. Put reverse lever in extreme back notch and mark valve stem at gland. Throw lever in extreme forward notch and move eccentric until mark on valve stem shows at gland. Tighten set screws. Be sure that the throw follows the pin in that eccentric's motion. This is setting the slipped eccentric by the one that is not slipped. Or place the slipped eccentric with the throw at a right angle behind the pin and move it toward the pin enough to allow a little steam to escape from the front cylinder cock. Tighten set screws. This is setting an eccentric by the cylinder cock.

Q. 24. Would an engine be square, setting an eccentric in this manner?

A. Perhaps not, but as good as could be done without trams, and perhaps better than is often done with them.

Q. 25. Is it advisable to mark eccentric straps and blades so that in case they slip they can be set quickly?

A. Yes. To avoid delay. This can only be done when engines are regularly assigned. The marks made by one man might mean nothing to another.

Q. 26. How can repairs be made for a broken cam or cam bolt?

A. Take off broken parts. Disconnect on disabled side and cover ports. Clamp valve stem. If a cam bolt to a back-up eccentric that is not keyed on axle should break, loosen set screws, oil freely between cam and axle, and, working the lever well down on the quadrant, go ahead with the train.

A bolt can sometimes be found to use in case of a broken cam bolt, but if not, as a rule, it will be necessary to disconnect.

Q. 27. What can be done in case of a broken eccentric strap?

A. Secure a longer bolt and fasten blade of broken strap to good eccentric strap. If this can not be done easily, disconnect. In case it is done engine must not be reversed.

28. Disconnecting for Broken Steam Chest.—"How would you disconnect for a broken steam chest?"

Answer.—This all depends on the style of chest and the extent of breakage. If the walls of the chest were broken so they could be drawn together, would slack off nuts on steam chest studs and drive wedges or nails between the studs or chest to bring the parts together. Then tighten nuts on studs and proceed. If this could not be done, would disconnect valve rod and remove chest, blocking

over the steam ports leading to the steam chest and put the cover on blocks, bolting it down hard on the wooden blocks by tightening the nuts on the steam chest studs. Would not take down main rod, as lubricant could be introduced through the admission ports to the cylinder. If studs were all gone and the cover broken, would prepare to be towed in. Do not try to put in blind gasket in steam pipe joint, as it is impracticable to do so out on the road.

29. Broken High-Pressure Cylinder Head.—"Is it practical to try to clamp a board over the high-pressure cylinder head, using live steam in the low-pressure cylinder on a Vauclain compound?"

Answer.—No. In case of a broken high-pressure cylinder head, block the valve central on that side, cover the ports, disconnect the main rod and block the crosshead, same as with a simple engine. Run in with the other side.

30. Slip of Link Block.—"What is the exact cause of the slip of the link block, and does it increase the travel of the valve?"

Answer.—The exact cause of the link slipping on the link block is due to the link block being securely fastened to the bottom of the rocker arm. Therefore, the block must move in an arc traversed by the rocker arm, and the action of the eccentric rods on the link forces it to move in a vertical motion at certain parts of the stroke, which causes the link to slip on the block. When one eccentric is traveling forward and the other backward the link must move, but the block does not, hence the slip. The longer the cut-off the greater the slip.

31. Blocking Links.—"I have a book where it says that in the event of a tumbling shaft arm broken you should block up one link by putting block above link block, and if necessary to back up you must reverse the

block to lower end of the link. I am satisfied that the information in regard to blocking for the reverse motion is incorrect and that you should simply substitute a longer block between the top of the link and the link block. Please advise which is correct."

Answer.—When the link is blocked on account of a broken reach-rod, link hanger or saddle pin, there should be a block placed between the top of the link and the link block, in position to insure the handling of the train in forward motion, and a block between the link block and the bottom of the link, allowing enough space between the blocks for the slip of the link on the link block. Then when it is desired to block the link for the back motion the blocks should be reversed, placing the long block on top of the link block and the short one at the bottom of the link. This is, very likely, what was intended to be understood by reversing the block in the book referred to, and is correct.

32. Broken Hanger at Back End of Long Equalizer.—"If you broke hanger at back end of long equalizer what would you do?"

Answer.—Remove the broken hanger and chain back end of long truck equalizer to cross-equalizer.

33. Blocking for Broken Reverse Lever or Reach Rod.—"In blocking a broken reverse lever or reach rod is it good practice to block on top of both links, or to simply block one link at a cut-off where engine will handle train? If both links were blocked would not the slip of the link-block cause the wooden blocks to be pounded to pieces and possibly damage the link motion?"

Answer.—In case of broken reverse lever or reach rod it may be possible to block the tumbling shaft arm in the running board, if not, sometimes it may be advisable to

place a bar of iron or wood across the top of the frame under the link arms to hold the links in position to give the required cut-off, but the blocking and arms should be securely fastened. When blocking the links to hold them in position it is better to block only one link. Even if working in full gear a small block should be placed between link block and top of link to prevent damage by an increased travel of the valve. Blocking one link will answer the purpose. If both links were blocked solid there would be no chance for the link to slip on the link block and damage would result to the link motion.

34. Guides and Cross-Head Not in Line.—"What would be the result if guides and cross-head were not in line"

Answer.—Excessive wear on sides of cross-head and guides, unequal wear in cylinders and cylinder packing rings, difficulty in keeping piston rod packing from blowing and wearing out rapidly, and trouble with main rod brasses, especially in the front end of main rod.

35. Changing Eccentric of Direct Motion Engine.—"Will changing the eccentric of a direct motion stationary engine with D slide valve having lap and lead, placing it one-half way around the shaft from its former position, change the direction of the engine's running, or will the engine run at all?"

Answer.—If the engine had a valve without lap or lead the eccentric would be set at right angles to the pin, or at 90 degrees, and changing the position of the eccentric one-half way around the shaft would reverse the motion and cause the engine to run in the opposite direction. When lap is added to the edges of the valve, and given lead, this is called the angle of advance, and the rule is to set the eccentric ahead of the pin at an angle of 90 de-

grees, plus the angle of advance. This rule would hold good if it was desired to have the engine run in either direction, and if you changed your eccentric 180 degrees steam would be admitted behind the piston when the engine was on the forward center. Therefore, she would not run at all. See illustration, Figs. 1 and 2, which show the position of the valve with the eccentric in that position. But if the eccentric was given the same angle of

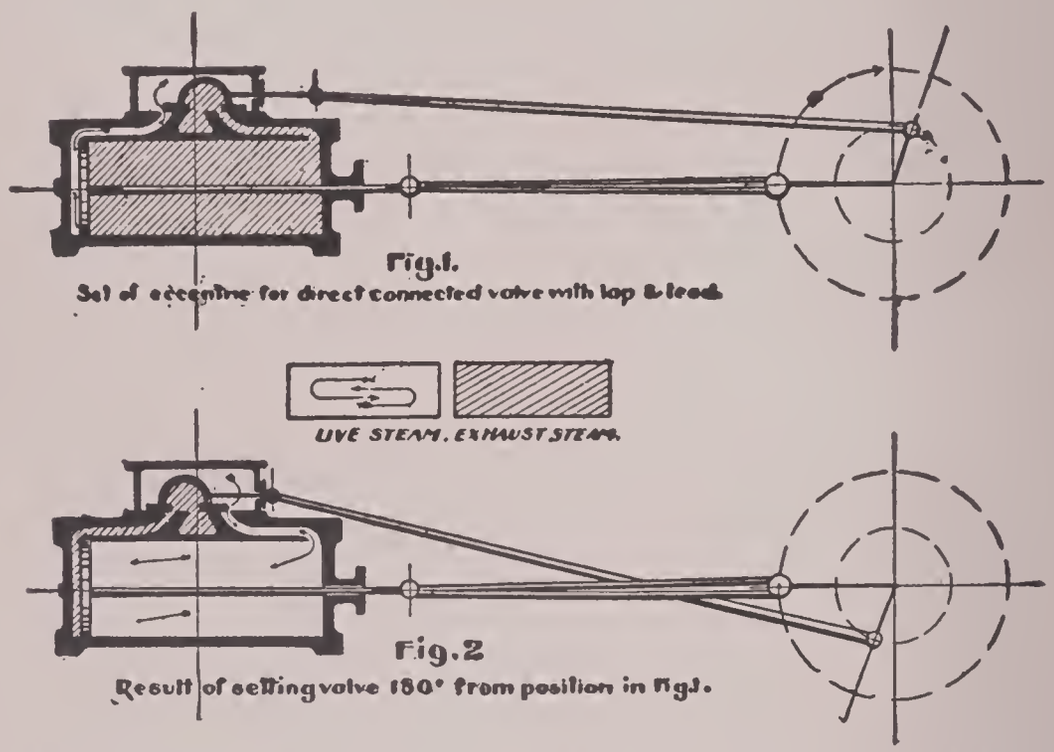


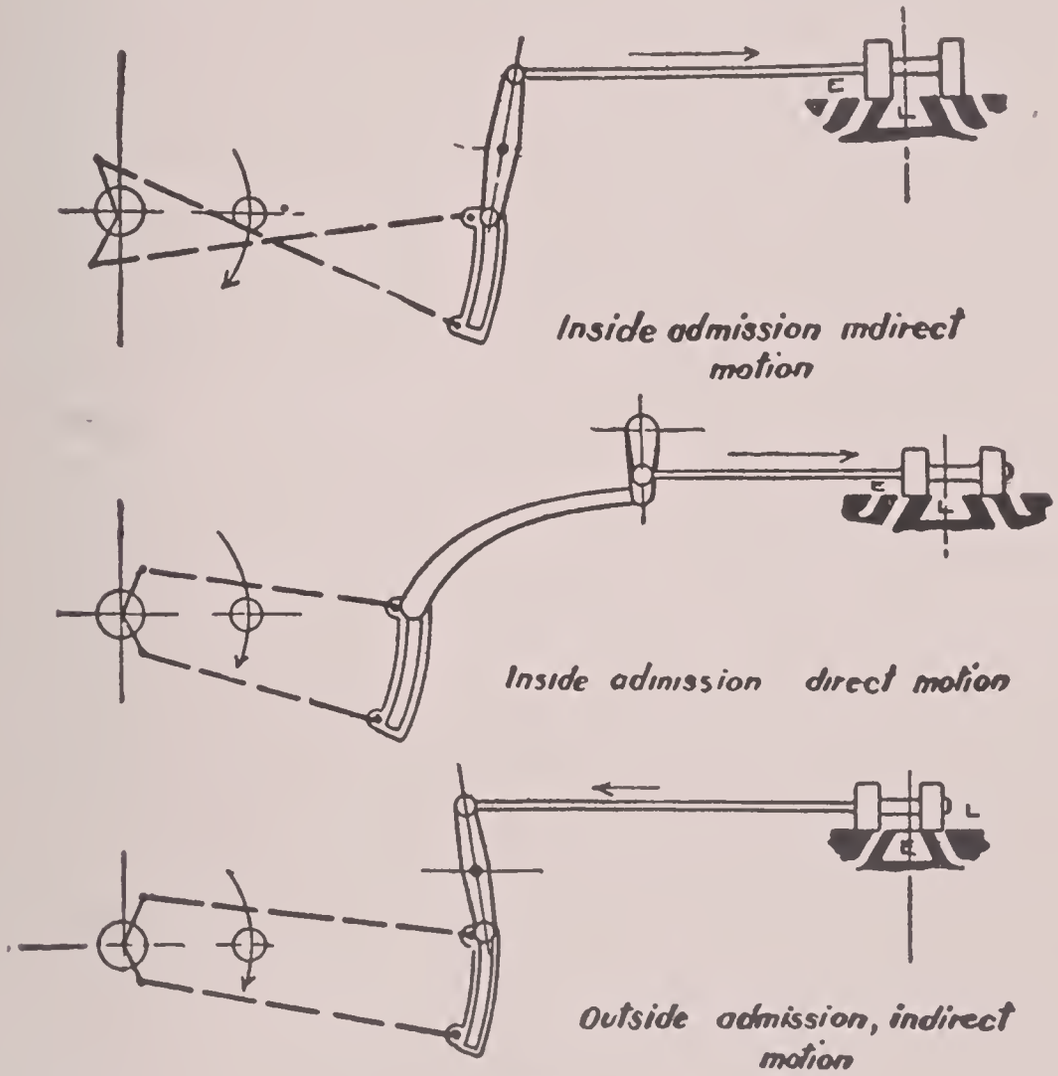
Fig.1.
Set of eccentric for direct connected valve with lap & lead.
LIVE STEAM. EXHAUST STEAM.
Fig.2
Result of setting valve 180° from position in Fig.1.

Diagram Illustrating the Effect of Changing the Eccentric on a Direct Motion Engine.

advance in Fig. 2 ahead of the pin, steam would be admitted ahead of the piston, and the engine would run in the opposite direction from that taken when eccentric and valve are as in Fig. 1.

36. Eccentric Most Likely to Slip.—"Which eccentric is most liable to slip, the go ahead or the back up, and why? Which way will it slip?"

Answer.—The forward motion eccentric when running forward and the back motion eccentric when running backward, because they are more nearly in line with the link block in either motion and, therefore, controlling the valve. You can readily understand that when the engine is in full gear forward, the forward motion eccentric rod



Illustrating Different Motions.

is nearly in line with the link block, and the work of moving the valve is done by the forward motion eccentric, and this proportion of work will hold good in relation to the position of the link block in the link. The back motion eccentric is only holding the bottom of the link, and the

work done by the back motion eccentric is very light when the lever is in this position, and when they slip on the axle they usually slip back, or away from the work, just the same as a man walking forward and pulling a load would slip backward, or if walking backward under the same conditions and would slip, he must slip forward.

37. Setting a Slipped Eccentric.—"How would you set a slipped eccentric?"

Answer.—If the forward motion eccentric was slipped, would place engine on forward center on that side, put the lever in full gear back motion and make a mark on the valve stem even with the gland, then put the lever in full gear forward and move forward motion eccentric until the mark on the valve stem showed in same position as when it was made. This is simply setting the slipped eccentric by the good eccentric. You can obtain quite good results by placing the engine on forward center, lever in full gear forward, open the cylinder cocks and move the eccentric until steam shows at the forward cylinder cock. This will get you in and is much quicker. The same method can be employed in setting a back motion eccentric that has slipped.

38. Sectional Eccentric Slipped.—"If a sectional eccentric is slipped and you cannot move it on the axle to get it back in position, what should be done?"

Answer.—The section bolts should be slacked up enough so it can be moved easily, and, after it is in proper position, and before the set screws are set up, the section bolts should be drawn up tight again.

39. Right Go-Ahead Eccentric Slipped.—"If the go-ahead eccentric on the right side is slipped, by following these directions will it be properly set? By placing the engine on top quarter and putting the reverse lever in

extreme forward corner, then take out bolt on top of link clevis, put reverse lever in back corner, and drive eccentric back so as to put in bolt?"

Answer.—This method is not accurate enough to recommend your wasting any time trying to prove it. Why not place engine on forward center with lever in full gear forward and move eccentric until steam shows at front cylinder cock? This will require less time and there is no chance for a mistake. In case you want to set the eccentric by the position of the link, place engine on forward center, hook reverse lever in the center notch, then tie a nut to a piece of string and fasten it to the eccentric-rod bolt at the top of the link, and move the eccentric on the axle until the spring is plumb with both the eccentric-rod bolts. This will be more satisfactory than the directions given in the question.

40. Setting an Eccentric on the Road.—"What is the best and quickest way to set an eccentric on the road?"

Answer.—Place engine on forward center on side that the eccentric is slipped. If it is a forward motion eccentric that is slipped, put the lever in full gear forward, open cylinder cock, crack the joint on the throttle open and move eccentric until steam shows at front cylinder cock. If back motion eccentric has slipped, put the lever in back gear and move eccentric until steam shows at front cylinder cock. This is the quickest way to get in with your train. Placing the engine on forward center gives you a better chance to get at the eccentrics, and when the piston is at the forward end of the cylinder steam must be admitted to the forward steam port to move the engine either backward or forward.

41. Broken Eccentric.—"Would it work, if the

back-up eccentric broke while running ahead, to take one bolt out of the good eccentric blade, and bolt the eccentric blade of the broken eccentric to it, and proceed without disconnecting, or vice versa?"

Answer. Yes. That is all right for forward motion, but the link should be blocked, so that there would be no possibility of reversing the engine. In case you were backing up and broke the forward motion eccentric the same thing could be done with the forward motion blade, but not if you were running ahead. In either of the above breakdowns, when the back end of the blade is bolted to the strap of the good eccentric, the blade only serves to hold the link in position and prevent it tipping or turning over, but the link should be blocked to prevent reversing, and the good eccentric would govern the movement of the valve while in that position. If the forward motion eccentric would break while running ahead and the back one on that side could not be substituted, and the eccentric could be moved on the shaft, the back motion eccentric could be moved to correspond with the position of the forward motion eccentric, and by disconnecting the link hanger and blocking the link the train could be taken in in forward motion.

42. Broken Go-ahead Eccentric Strap or Blade. —"In case of a broken go-ahead eccentric strap or blade, suppose I should remove the broken parts and tie the top of the link to the lower arm of the tumbling shaft, set the valve to cover the ports and tighten the gland a little to prevent the gland from being too loose, but not tight enough to prevent reversing, and allow the valve to be moved by hand to get oil to the cylinder while drifting. Would this be practicable?"

Answer.—It is the rule to take down both eccentrics

in a case of this kind, because, when a rule is made, it is of general application. If the tumbling shaft has the link arm over the top of the link, and it could be secured near its proper position, it would be safe enough if the lever was not hooked up or reversed, but in case of a flag or an emergency and the engine was reversed, further damage would result. It would be safest to take down both eccentric rods. However, if this should happen to you where an engine was not available and train could not be handled on one side, if you could turn the engine on a Y or a table, ask train dispatcher to let you turn engine around; get on to the train and back up to the terminal, keeping the lever in full gear back motion. This would bring the back motion eccentric rod nearly in line with link block on the disabled side, and would enable you to work both sides of your engine and take in your full train, which would be a credit to you. Such work is usually appreciated.

43. Broken Eccentric Strap, Forward Gear.—"If you break an eccentric strap, the forward gear, how would you disconnect?"

Answer.—If going to back up to terminal, would use long bolt to secure back end of forward motion eccentric rod to the back motion strap and use both sides. Would block link to prevent a possibility of reversing the engine while under these conditions. If was going ahead would remove broken strap and rod, also link hanger and let link ride on link block. Would disconnect valve stem and clamp it, leaving one port open sufficient to let enough steam into cylinder to prevent damage, and proceed in the usual manner without taking down main rod.

44. Back Motion Eccentric Strap Broken.—"If the back motion eccentric strap was broken and the

blade was coupled to the forward motion blade with a long bolt, could the engine be run backwards with its own steam, and vice versa? Explain what action this trouble has on the valve."

Answer.—If the back motion eccentric strap was broken and the blade was connected to the forward motion strap by a long bolt, as you state, if the blade was the same length and the engine was reversed, or the lever put in the back motion, the disabled side would be working steam in the forward motion while the other side would be working it in the back motion. In order to get the engine to back under these conditions, it would be necessary to slip the forward motion eccentric around to the position opposite that of the back-up. That would be the only way you could work steam in both motions in both directions, using both sides of the engine.

45. Broken Back Motion Eccentric.—"If you were running an engine on a busy piece of track and *broke the* back motion eccentric, what could you do to facilitate clearing the track for other trains?"

Answer.—The engine can be run in forward motion by securing the bottom of the link stationary and working engine in full gear. Sometimes this is readily accomplished by bolting the back motion eccentric rod to the forward motion eccentric strap, using a long bolt and filling in the space between both rods with a block or large nut. This will hold the bottom of the link slightly back of its original position when the back motion eccentric rod was coupled to the strap of the back motion eccentric, but it is a convenient and positive fastening. There should be a block placed between the bottom of the link block and the bottom of the link to prevent the engine from being reversed while running under the above conditions.

46. Eccentric Straps Broken Off of Flanges.—"What could be done if forward or back motion eccentric strap should break off of the flange on both sides?"

Answer.—This is rather an unusual occurrence, and the safest thing to do in a case of that kind would be to take the engine down on that side or handle it the same as you would a broken strap, although if it was the eccentric strap next to the box that was broken and in your judgment you could bring your train into the terminal without further delay or consequential damage, it would be exercising good judgment on your part to do so; but to give an answer to this question the only safe thing to do would be to take her down on that side.

47. Failure to Observe Proper Precaution with Broken Eccentric.—"In the event of not disconnecting when the back motion eccentric was broken, what would be the effect if the lever was not left at full stroke?"

Answer.—Consequent damage to the valve gear, resulting in trouble for yourself and expense to your employer. If the eccentric was broken it would run hot and break or pound the strap to pieces. Then the back end of the eccentric rod would fall down and strike the ties, and the pressure of the valve would cause the link to tip and slide over the link block, because there would be no fastening for the bottom of the link. Do not take chances on breeding trouble. If the back motion eccentric rod was fastened to the forward motion strap the engine would be slightly lame as you hook lever up toward the center, and if the lever was put in back gear the disabled side would work in forward motion and the good side would be working in back motion. Thus the reason for blocking between the bottom of the link block and the link.

48. INDIRECT MOTION ENGINE.—"With an indirect motion engine, doesn't the back-up eccentric always lead the pin a quarter of a turn less the lap and lead?"

Answer.—With an indirect motion the back motion eccentric leads the pin when the engine is running ahead, and follows the pin when backing up. It is proper to say, with this motion, that either eccentric follows the pin in either direction that the engine is running. (See Fig. 1.)

49. DIRECT MOTION ENGINE.—"With a direct motion valve gear, doesn't the go-ahead eccentric lead the main pin about a quarter of a turn?"

Answer.—A direct motion gear, inside admission valve, the eccentrics are set the same as in Fig. 1. Note Fig. 2, which shows the arrangement with the inside admission valve and direct rocker.

Fig. 3 shows the position of eccentrics if an outside admission valve were used with a direct rocker.

Fig. 4 brings you back to the starting point, only with a piston instead of a slide valve.

50. DIRECT VS. INDIRECT VALVE MOTION.—"There is a great difference of opinion as to whether a certain class of our engines are direct or indirect valve motion. They have inside admission piston valves with a transmission bar, and the go-ahead eccentrics following the pins, same as in ordinary indirect engines. Please advise what they are, direct or indirect engines."

Answer.—Fig. 1 shows an inside admission piston valve with an indirect rocker. You will observe that the position of the eccentrics on the shaft or axle is directly opposite to the position that they would be in if this was an outside admission valve. Instead of being advanced toward the pin the amount of lap and lead, they are ad-

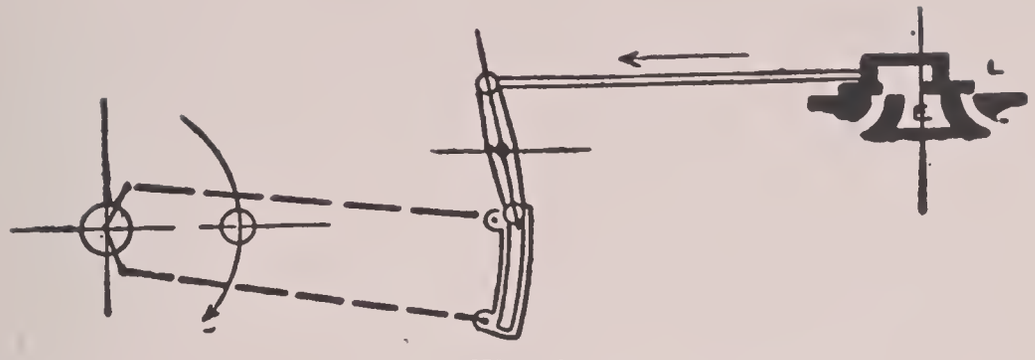


Fig. 1.

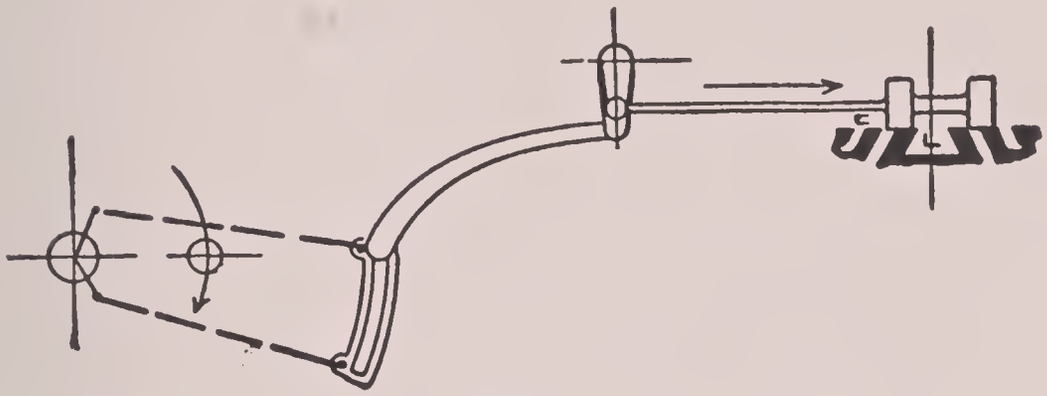


Fig. 2.

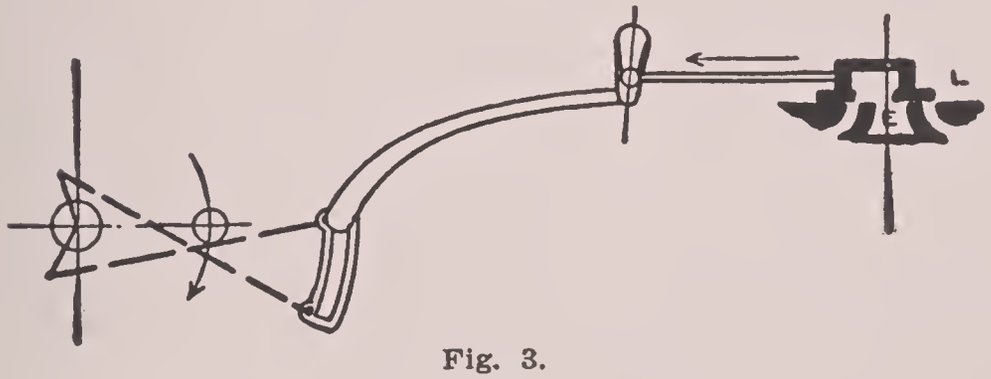


Fig. 3.

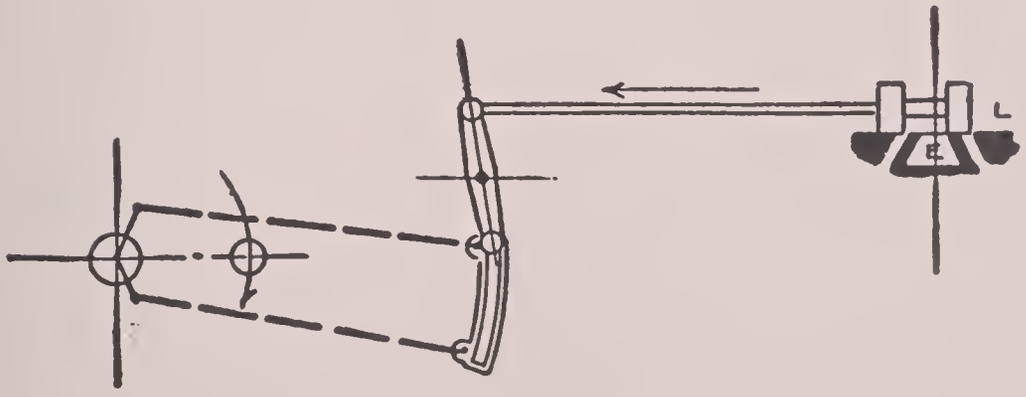


Fig. 4.

Direct and Indirect Valve Motion. Illustrating Questions 48 and 49.

vanced away from the pin. The internal or external admission valves make this change of position of the eccentrics necessary with an indirect rocker. This illustra-

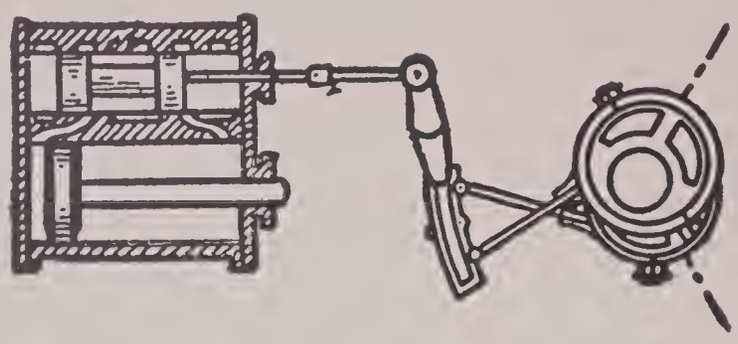


Fig. 1

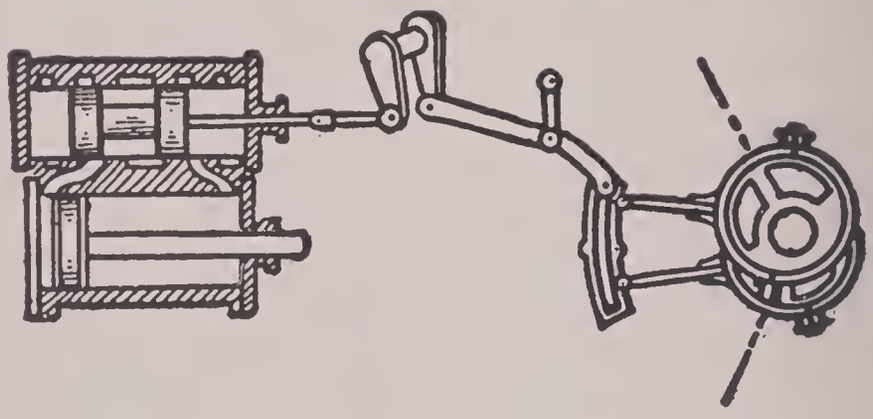


Fig. 2

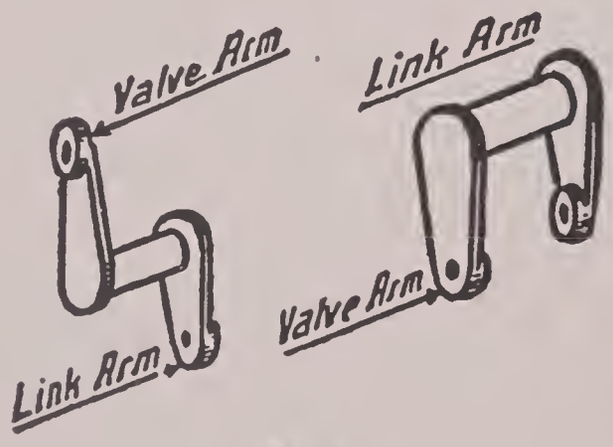


Fig. 3

tion is a view of an indirect motion or rocker, because the valve is traveling in one direction and the eccentric is traveling in the opposite direction. Fig. 2 shows the

same kind of a valve with inside admission, but with a direct motion or rocker, and the eccentric and valve both move in the same direction. In this illustration the eccentrics are placed on the shaft in the same position as if you had an indirect rocker with an outside admission valve.

The front steam port must be opened to admit steam to the cylinder in both illustrations. If your engine is put up as shown in Fig. 2 you have a direct motion engine. Fig. 3 shows an indirect rocker on the left and a direct rocker on the right, or a rocker with a link arm and the valve arm opposite each other is a direct rocker.

51. Working Steam Expansively.—"What is meant by working steam expansively?"

Answer.—Working steam expansively is the work done by the expansive force of the steam; after the valve has closed the port at a certain part of the stroke, then the steam thus confined in the cylinder forces the piston to the end of the stroke by its expansive force. Expanding in volume the pressure becomes less. To make it clear to you, there are four terms used in speaking of the action of steam in the cylinder. When the valve closes the port it is known as "cut-off," and the cut-off is regulated by the position of the reverse lever. Then the expansion of the steam thus confined in the cylinder forces the piston to the end of its stroke. This is called "expansion." When the valve opens the port for the escape of steam, this is called "exhaust," and the steam that does not get out of the exhaust port while the valve is open is confined in the cylinder and compressed by the piston on its return stroke. There you have admission, expansion, exhaust, and compression.

52. Point of Cut-Off.—"Lap of valve is 1 inch,

travel of valve is 5 inches, no lead, stroke of piston is 24 inches; at what part of stroke will the steam be cut off?"

Answer.—This depends entirely on the position of the reverse lever. Place the engine so that the piston is at any desired part of the stroke and move the reverse lever to bring the valve in position to just close the port or cut off the admission of steam to the cylinders, and you will get the part of the stroke at which steam will be cut off with the lever in that position. For instance, in case you desired to make your quadrant at a certain notch, say 5 inches, you would move the crosshead back 5 inches from the end of the stroke, then move the lever so the port would be closed for admission, this would give you a 5-inch cut-off with the lever in that position, and the position for the lever to obtain other cut-offs at different parts of the stroke could be determined in the same manner.

53. Expansion and Cut-Off.—"How is expansion increased as the reverse lever is hooked toward the center, and does the valve travel slower in relation to the piston with a 6-inch cut-off than it would at full stroke?"

Answer.—In speaking of expansion, we mean the work done by the expansive force of steam pushing the piston to near the end of the stroke, if the steam is cut off or the port closed by the valve. If the lever is hooked toward the center the steam is cut off earlier in the stroke. The stroke of the piston is constant and can not be changed, say 26 inches or 28 inches, and when the lever is in full gear steam is admitted to the cylinder nearly its full stroke, but by hooking the reverse lever up the travel of the valve is shortened and the port is closed, cutting off the steam when the piston has made only a

portion of its stroke. Therefore the shorter the cut-off the greater the expansion, as the steam confined in the cylinder will expand until the piston reaches the part of its stroke where the port is opened for steam to escape, or what is known as the opening of exhaust. The valve must travel over its seat at full stroke twice the lap and twice the width at port opening. At six inches cut-off it would travel twice the lap and port opening, but as the port would not be full open it would not travel as far or as fast as it would at full stroke. When at full gear the link block would be nearly opposite the eccentric rod and the rod would control its movement, but at short cut-off it receives its motion from near the center of the link and both eccentric rods. Look this over when you are under an engine, and have the lever moved from full gear to 6-inch notch; it will help you to understand it.

54. Expansion vs. Valve without Outside or Inside Lap.—"Would there be any expansion if a valve without any outside or inside lap was used and the reverse lever hooked up to the 6-inch notch, or where the engine cuts off steam at 6 inches with a valve having a lap?"

Answer.—The advantage of lap on a valve is that steam may be used expansively. The lap of the valve closes the port at the point of cut-off and the steam expands in the cylinder until the port is opened for the exhaust. If we used a valve that had no lap the outside and inside edges would register with the edges of the steam ports, and the least movement of the valve would give steam admission at one end of the cylinder and exhaust at the other. You could not use steam expansively with a valve without lap. In this case you would have the eccentric set at right angles to the pin. When lap is

added to the valve and the engines given lead, the eccentric is advanced that amount from right angle.

55. ADJUSTING THE CUT-OFF.—"In running over the cut-off on an engine I found she carried steam too far on one side, and I found it necessary to shorten link hanger on that side. Engine cut off steam on the right side at 9 inches, both ends, and on the left side she cut off at 8 inches, both ends. I marked the link block and then raised the link ¾ of an inch, and again run over the cut-off and found by raising the link ¾ of an inch it made 1¾ inches difference in the cut-off. Now, I want to know how to use proportion so I can shorten the hanger in proportion to the ¾ of an inch I raised the link, so I can get the desired cut-off of 8 inches on that side of the engine?"

Answer.—A rule of proportion can not be given that would be accurate, although it may be obtained approximately by comparing the length of the link from center to full gear, to the cut-off. For instance, the cut-off in full gear is 24 inches on an engine with 26-inch stroke and the distance from the center of the link to the point opposite the blade pin when in full gear is 6 inches. Then ¼ inch on the link would represent 1 inch on the cross-head or cut-off. If the link hanger is not the proper length, the difference would be greater in 7 or 8 inches than in 15 or 20-inch cut-off. It was a mistake to shorten the hanger ¾ inch to obtain 1 inch less cut-off, as 3-16 would possibly have made it about right,

A sure method of ascertaining the correct amount to shorten the hanger would be to place the cross-head at 8 inches, the desired point of cut-off for that side, then mark the link, next raise or lower the link, as the case may be, by moving the reverse lever until the port mark

on the valve rod or stem comes to the tram, then mark the link again at that point, and the difference between the two marks on the link will be the amount that the link hanger should be changed.

56. Position of Saddle Pin.—"Why is the saddle pin placed back of the center of the link, instead of in the center?"

Answer.—This is to equalize the cut-off. Please note that if you place the engine at mid, or half stroke, and use a tram equal to the length of the main rod, or the distance from the center of the crosshead pin to the wheel center, and describe an arc to that radius on wheel and tire, you would find that the tram point would mark the tire forward of a perpendicular line drawn through the center of the axle, and the shorter the main rod the farther away from the perpendicular line the tram point would be, showing that the difference would increase with a short main rod and decrease with a long main rod. Now, if you move the engine from half stroke to forward center and back to half stroke, you would not move half the circumference of the wheel, but only the difference measured on the tire between the two marks made by the tram, and while you move the engine from half stroke to back center and to half stroke again, the engine would move a greater distance than on the first half of the stroke. This is due to the angularity of the main rod. Therefore, it is necessary to locate a position for the saddle pin so that equal portions of steam may be admitted alternately into the cylinder, and the cut-off be equal when the crank pin is at half stroke. This is usually accomplished by locating the point of suspension of the link back of the center, and is for the purpose of securing equality of cut-off and overcoming the angular-

ity of the main rod and the inequality in the motion of the piston at half stroke,

57. Position of Saddle Pin Relative to Link.—"Why is a link block not put in the center of a link? As I understand, it is not."

Answer.—We presume that you refer to the saddle pin which is set back of the center of the link. You understand that the length of the main rod is the distance from the center of the angle to the center of the crosshead pin when the crosshead is in the middle of its stroke. Then with a radius equal to the length of the main rod, if you describe an arc, it will intersect the tire or circumference of the wheel forward of a vertical line drawn through the center of the axle, indicating that the wheel travels farther while the crosshead travels from the half stroke to back center and to half stroke, than it does from half stroke to forward center and back to half stroke. This is due to the angularity of the main rod, and increases as the length of the main rod decreases, *i. e.*, the difference is greater with a short main rod than a long one. The imperfections thus introduced by the main rod are imparted to the valve motion. To overcome it and obtain an equality of cut-off for both ends of the cylinder, the saddle pin is set back of the center of the link. The amount is usually determined by the result of experiment on the different motions.

58. Purpose of the Link.—"What is the purpose of the link ?"

Answer.—The purpose of the link is for reversing the engine and varying the rate of expansion or cut-off. The amount of travel communicated to the valve depends on the distance the link block is from the center of the link. By moving the link up or down on the link block,

the travel of the valve will either be increased or decreased. On account of the ease with which it may be handled on engines, which of necessity have to run backward or forward, it is considered the most desirable for an engine requiring a reversing gear.

59. Cylinder Packing Rings.—"What keeps the cylinder packing rings steam tight when snap packing rings are used? Why can not steam go through the one joint in the first ring, then go around and go through next joint until it went clear through?"

Answer. Cylinder packing rings are turned slightly larger in diameter than the cylinder, and when the ring is placed in the piston it has a slip fit in the groove and the steam that enters the joint will go under the ring and balance the pressure on the outside of the ring and usually overcome it if the ring is in fair condition. You have the spring in the ring and the steam pressure that goes through the joint, tending to force the ring outward or against the cylinder walls, and, the cylinder walls being colder than the steam, the steam is condensed and the condensation helps to keep the packing rings tight. Of course, when the ring becomes worn it loses its set or spring, and if the cylinder is worn out of round, or cut, the space between the rings and cylinder walls is so great that the steam will blow through.

60. Back-Set of Rocker Arm.—"Why is a standard rocker arm back-set?"

Answer. A straight line engine is so called by reason of the wheel center and cylinder center being on a horizontal line, which is called the center line of motion, and a straight rocker is used for a rocker arm with no back-set. If the center of lower rocker arm is below a line drawn through the center of the axle and the center of

the cylinder, there must be back-set in the rocker so that it will travel an equal distance each side of a vertical line drawn at right angles to the line of motion. Plumb the top arm of the rocker, then draw a line from center of axle to center of lower rocker arm and give it back-set enough to bring center line of lower rocker arm at right angles to the line of motion,

61. FINDING STROKE OF PISTON.—"What stroke of piston should be given to a locomotive with a cylinder diameter of 17 inches; weight on drivers, 85,000 pounds; diameter of drivers, 56 inches; and a boiler pressure of 180 pounds per square inch?"

Answer.—The tractive power not being given, we will base it on the tractive weight. Allowing a ratio of 4.5 to 1, or, 85,000 pounds, the weight on drivers, divided by 4.5=18,880, or 18,880 pounds tractive power. Then from the formula for getting the tractive power, which is

$$T=\frac{C^2\times S\times P}{D},$$

to get the stroke of the piston we will work the example the other way, or deduce the following formula obtained from the above:

Taking size of cylinder and driver with same pressure, which is 85 per cent of boiler pressure, we have,

$$S=\frac{56\times 18{,}880}{17^2\times 85\%\text{ of }180}$$

$56\times 18{,}880=1{,}057{,}280.$
$17^2=289,$
$85\%\text{ of }180=153.$

Then $153\times 289=44{,}217$, and $1{,}057{,}280\div 44{,}217=23.9+$, or 24-inch stroke of piston for above engine.

*WALSCHAERT VALVE GEAR.

Question 1. Define the meaning of the term "valve motion."

Answer. The gear, or arrangement of rods, levers, etc., actuating the valve that admits steam from the boiler to the cylinder of an engine and finally exhausts it therefrom is referred to as the valve gear, or valve motion; it is the expansive force of the steam in the cylinder that drives the piston, which in turn, through connecting rods, forces the driving wheels to turn around and move the locomotive. The valve gear includes the mechanism by which the engine may be reversed as to the direction in which it runs, through altering the steam distribution; and the reversing mechanism is further employed to fix the degree of steam admission to the cylinder and its retention there in proportion to the stroke of the piston.

Q. 2. Name the different parts that comprise the Walschaert valve gear as shown in the photo-engraving of the motion work of the Baldwin engine in Fig. 1.

A. In Fig. 1, pointer No. 3 rests on the link which is suspended by a fulcrum pin, or trunnion, at its exact center, from a bracket attached to the guide-bearer, or yoke; the lower extension of the link, the link foot, is indicated by pointer No. 9, and the eccentric by No. 7,

*W. W. Wood, in Locomotive Firemen and Enginemen's Magazine.

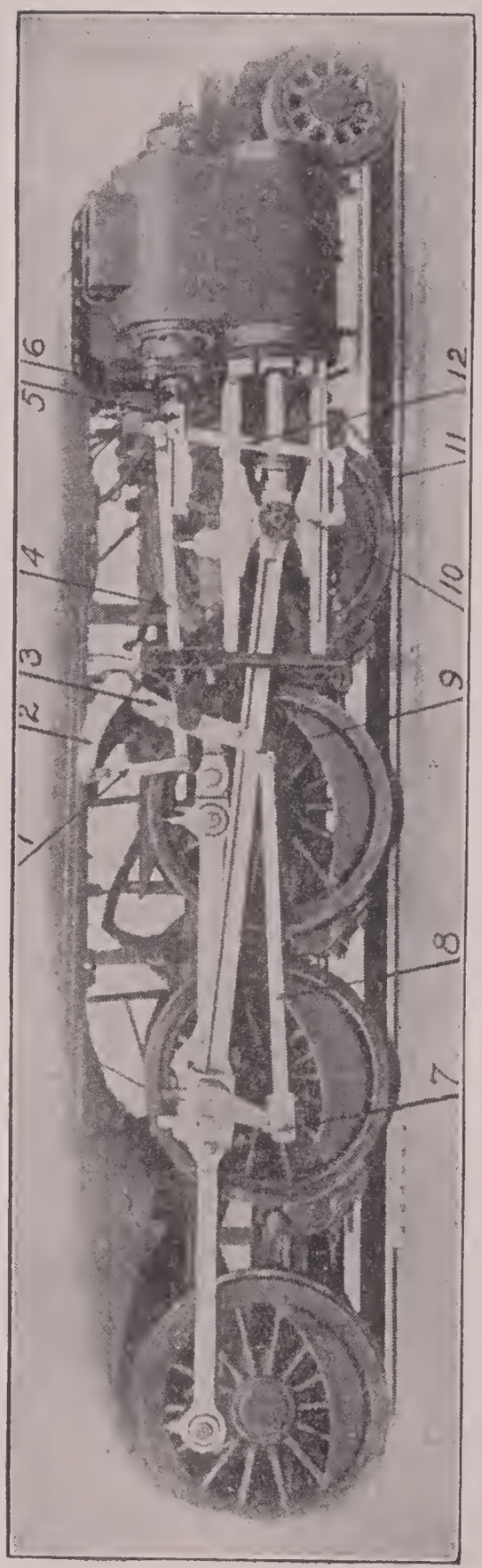


Fig. 1. Walschaerts Valve Gear applied to Consolidation Locomotive, Pennsylvania Railroad (Baldwin Locomotive Works).

while No. 8 points to the eccentric rod and No. 4 to the radius rod; No. 2 indicates the reversing, or lifting, arm, from which the radius rod is hung by the suspension bar denoted by pointer No. 1; the valve-stem slide, No. 5, acts as a cross-head in carrying the valve-stem, No. 6, and the combination lever, No. 12; the piston's motion is imparted to the lower end of the combination lever through the cross-head arm, No. 10, and the vibrating link, No. 11, and it may be well to state that the combination lever is called the vibrating arm by some locomotive builders. The valve of the engine shown in Fig. 1 is of the piston type, with "inside admission."

Q. 3. What is meant by the "expansive force" of the steam?

A. For the production of power, matter must first be changed in form or state, and its effort to return to its original form or state creates a force that may be employed and controlled. Through the action of heat, water in a locomotive boiler is changed to compressed steam, and in its effort to expand—to fill a larger space—this force is created; when the steam is being released through the cylinders of an engine its expansion, to make more room for itself, forces the piston from it; as it expands its pressure lessens, but if steam is continually admitted to the cylinder during the whole stroke of the piston its power continues undiminished, because the comparatively small cylinder is receiving the expansive effort from the whole boiler, and in this case expansion really drives the piston, but the term is not made use of. If the admission of steam from a boiler pressure of 100 pounds to a cylinder with a piston stroke of 24 inches should be closed after the piston has traveled, say 12 inches, the pressure against the piston at the instant of

cessation of boiler supply would be, approximately, 100 pounds per square inch, but thereafter, as the piston was forced to advance in its travel, the pressure of the steam in the cylinder would decrease in inverse ratio to the increase in its volume—the increasing space between the piston and the pressure head of the cylinder—until, when the piston had completed its twenty-fourth inch of stroke, and if the exhaust had not yet commenced, the steam would have a pressure approximating 50 pounds per square inch, for the volume of the steam would then be twice what it was at the time of the cut-off of its supply. If the closure of the steam supply had been earlier in the stroke than 12 inches the expansion would have been carried further, and the steam finally released from the cylinder at a still lower pressure; but in a locomotive cylinder steam is never expanded down to a pressure lower than that which will produce the required power. In starting a heavy train expansion, as we term it, is not made use of, while the lighter the train and the faster it is run, the shorter will be the duration of steam admission to the cylinder, with a consequent increase in the length of expansive effort of the steam at each stroke of the piston. Steam is capable of doing work until it has expanded down to an equivalent of atmospheric pressure, and at that stage will still exert a force of nearly 15 pounds to the square inch if a vacuum be produced on the opposite side of the piston by complete condensation of the exhaust steam. The engine that shows the greatest economy in the use of steam is the one in which there is the widest difference between the cylinder pressures at the times of steam admission and release.

Q. 4. How many general types of locomotive valve motion are in use on American railways?

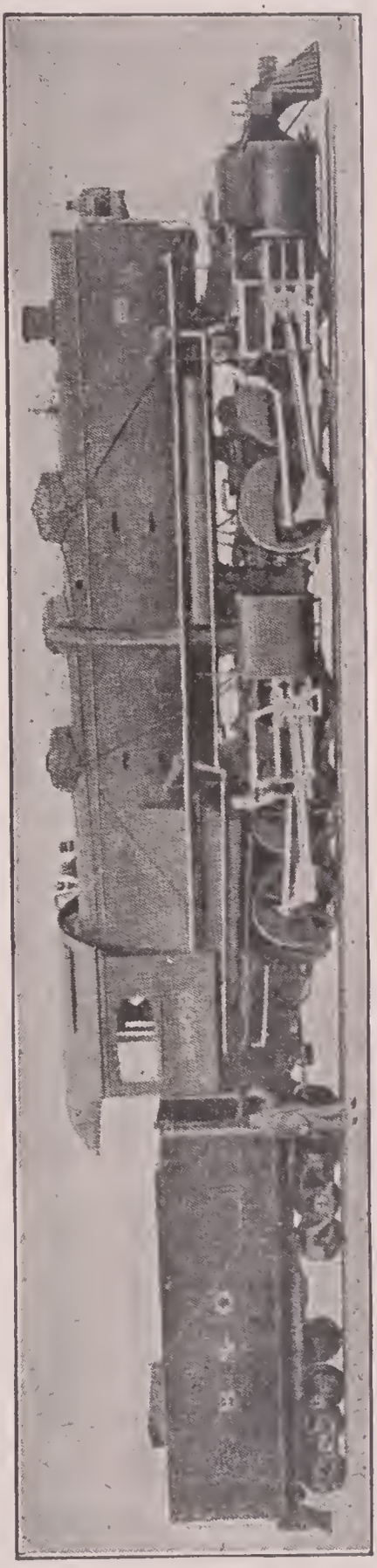


Fig. 2. Mallet Compound Locomotive, showing difference in set-up of Walschaert Gear between outside and inside Admission Valves.

A. There are two: The so-called "Stephenson" gear, or link motion, and the Walschaerts type. Both were invented at dates not so far apart, before the middle of the last century. The Stephenson gear, an Englishman's device, has been practically the standard American locomotive valve gear until the present century, while the Walschaerts motion, the production of a Belgian, has been the favorite on European railways. The Walschaerts gear has been given desultory trials in this country, but was never taken up with a serious intention of determining its merits until within the past few years.

Q. 5. From where does valve gear, of any type, receive its actuation?

A. As the valve controls the action of the piston its phases must be coincidental with certain regularly re-occuring phases of the piston's operation; therefore the valve must receive its motion from some point or combination of points in the machinery that is actuated by the piston.

Q. 6. What type of valve is required in association with the Walschaerts style of gear?

A. As with the common link motion, any type of valve that is in favor may be used with the Walschaerts gear. The valve is not regarded really as a part of the valve gear.

Q. 7. What is the principal difference between the Stephenson link motion and the Walschaerts valve gear?

A. Both systems employ a link for reversion of direction of motion, but in the Stephenson gear it is a "floating" link, of swing suspension, its motion imparted by two eccentrics attached to the main shaft, or axle, and raising or lowering the link past its central position causes the reversion, while a slight shift up or down will shorten

or lengthen the period of steam admission to the cylinders, because the valve receives its regular motion directly from a block carried in the slot of the link. The Walschaerts link is suspended by a fixed fulcrum pin, or trunnion, located at the exact center of the link saddle, to which it oscillates, and can not be raised nor lowered. The link receives its motion from a single eccentric, the forward end of which is connected to an extension of the bottom of the link, and the back end is connected to the eccentric, which is in the form of a return crank attached to the main crank-pin and set 90 degrees from it. The link and eccentrics of the Stephenson motion are inside of the engine frames, while the whole motion work of the Walschaerts gear is outside the frame, where the parts are better subject to inspection, lubrication and repair. A secondary, or modifying, motion, called lead, must be imparted to the valve, and this is secured in the Stephensons gear by advancing the position of the eccentrics on the axle, while by the Walschaerts method the location of the eccentric remains unchanged and lead is secured by the more accurate and stable method of a device called the combination lever. The lower end of the combination lever has a link-bar connection with the cross-head, and at its upper end and at an intermediate point on the lever closely adjoining are two other connections, the valve-stem and the radius rod. The valve-stem works on a guiding slide and supports the weight of the combination lever, carrying it in true position, while the back end of the radius rod is attached to the link-block. The lifting-arm of the reversing gear has its suspension bar attached to the radius rod, which it raises and lowers instead of shifting the link, as the reverse lever is thrown forward and back, and this chang-

ing of the location of the radius rod and link-block in the slot of the link either reverses the motion or shortens or lengthens the period of steam admission to the cylinders.

Q. 8. How many general types of valve are there in locomotive use?

A. There are many styles of valves, but all are embraced with the general types—slide valves and piston valves. A slide valve, or "D-slide valve," so called because in sectional side elevation it has the appearance of a reclining capital letter D, has a flat, plane face bearing on its seat, and the admission of steam to the ports to each end of the cylinder is past the ends of the valve, while the exhaust is through the inside cavity, and a slide-valve is, therefore, of "outside admission." If the total area of the top side of the slide-valve was exposed to the full steam pressure from the boiler, it would cause the valve to work very hard on account of its high frictional resistance, but slide-valves now have a large portion of the steam area balanced, causing them to work quite easily. Piston valves are in the form of a spool, the wide ends being really pistons similar to the main piston in the cylinder joined by the narrower tube of the spool, which is generally hollow, so that both ends of the valve chamber are in communication with each other, although some motive power officials use closed spools, as both ends of the valve chamber are otherwise in communication with each other. When piston valves are of outside admission the live boiler pressure occupies the ends of the valve chamber and the intermediate space between the pistons is open to the exhaust, so that the action is not unlike that of the D-slide valve. But most piston valves are of inside admission, wherein the ends of the valve chamber

are open to the exhaust and the middle space holds the live steam: this balances the valve, fore and aft, perfectly, as the areas inside of the valve are equal, while outside end pressures on the valve are unequal, due to the space occupied by the valve-stem with inside admission, also, there is no pressure against the valve-stem packing, except that of the exhaust steam. When outside admission valves start to open an admission port to the cylinder, either regularly or for lead, they must move in the same direction the piston will move, while an inside admission valve must go in an opposite direction to the resulting travel of the piston, so that the live steam can pass from the inside of the valve to the admission port; and while it is doing this the port from the opposite end of the cylinder is open to the opposite end of the valve chamber and the exhaust.

Q. 9. What is the theoretical position of the valve in relation to the piston, with either of the common types of locomotive valve gear?

A. With outside admission the valve is always one-fourth of a cycle of motion, or double stroke, ahead of the piston; inside admission valves follow the piston by that distance.

Q. 10. What is meant by direct or indirect valve motion?

A. Valve motion is direct when there is no reversion in the line of motion between the eccentric and valve; indirect when there is such reversion, as by the double rocker-arms of the Stephenson link motion, etc.

Q. 11. What is lead?

A. It has been stated that a valve of outside admission should travel one-fourth of a cycle in advance of the piston, and to obtain this result with direct motion

the eccentric that actuates the valve must be located at a point on the axle, or wheel, just 90 degrees ahead of the main crank-pin—in respect to the direction in which the engine is to run under the influence of that eccentric—and with indirect motion the location of the eccentric is 90 degrees behind the crank-pin; but, with the eccentric so placed, when the crank-pin was on either dead center, at the beginning of a stroke—the valve would be exactly centered on its seat with both steam admission ports widely covered—"widely," for the valve is considerably longer than the distance between the outer edges of the two admission ports—and as the wheels began to turn from the action of the engine on the other side the piston on this side would have been carried some distance in the cylinder before the valve would have moved far enough to uncover the admission port. In common practice, however, an alteration is effected in admission—is advanced slightly further than its theoretical position, with the result that as the piston is nearing the end of its stroke, in either direction, the admission port will start to open. This gives a preadmission of steam against the piston that is expected to cushion the sudden stoppage of the motion work, and to provide a full opening for steam admission earlier in the course of the piston's stroke. This preliminary opening of the admission ports is referred to as the lead.

Q. 12. Does lead have any further effects than those just stated?

A. Yes; all of the regular events of the valve are hastened, and while steam will be admitted to the cylinder earlier in the course of the piston's stroke, it will be closed off correspondingly earlier; there is nothing in the matter of lead that can make the steam push against the

piston during a longer part of the stroke than it would if lead were not present; in either case steam is admitted to the cylinder during the time that the crank is describing a certain number of degrees on the wheel's circle, and lead brings those degrees of force back to a point where the crank is ineffective—the lead center—with a consequent loss of power. Lead also causes an earlier closing of the exhaust, which in turn creates an undesirably high degree of compression between the piston and the cylinder head toward which it is advancing.

Q. 13. Does not compression take place even though the valve should not be advanced for the purpose of securing lead?

A. Yes, with any valve having lap, if it should be exactly central on its seat when the piston has arrived at the end of its stroke, there would be compression, for the reason that as the piston is nearing the end of the cylinder the valve is commencing to cover the exhaust opening, and before the piston has completed its stroke the exhaust is so strictured by the constantly lessening area of opening that even if the exhaust port is not entirely closed when the valve is on center there will be a certain amount of compression between the piston and cylinder head. But with the mere absence of lead opening of the admission port there will be a considerable amount of compression, for after the exhaust has closed the valve will have to travel the distance of its lap before the admission port is edge-and-edge with the valve, and while the valve is doing this distance the piston is moving through an equal proportion of its stroke, but toward the finish, with the exhaust port covered. So, in almost any conceivable case there is enough back pressure toward the finish of the piston's stroke to cushion its stop and the

sudden reversal of the motion work, without the preadmission of live steam as lead for that purpose.

Q. 14. What is it that causes this inevitable compression?

A. It is due to the lap of the valve.

Q. 15. What is the lap of the valve?

A. As stated before, when the valve is centered exactly on its seat its front and back edges extend beyond the outside edges of the admission ports, and the distance that the valve so "overlaps" the ports is called the outside, or steam, lap, this with outside admission valves; with any kind of valve it is the distance the valve must be moved from an exactly central position on its seat until the admission port starts to open. With inside admission valves the steam lap is to the inside; the inner edges of the valve pistons overlap the admission ports by the same distance as do the outer edges of a slide-valve of the same moments. The expansive strength of steam could not be obtained in an engine cylinder if its valve was without lap, for the lap of the valve extends the time between the completion of the cut-off of steam admission to the cylinder and the commencement of the exhaust opening from the cylinder.

Q. 16. Then, in order to secure preadmission of steam to the cylinder, or lead, the valve must be advanced in its direction of travel a distance equal to the lap plus the decided amount of lead opening?

A. Yes; this should always be remembered.

Q. 17. What is the method of securing this valve advance with the Stephenson link motion?

A. It is accomplished by moving both the "go-ahead" and "back-up" eccentrics in the proper direction on the main shaft, or axle, as noted in answer to question 7.

Q. 18. How is lead obtained by the Walschaerts gear?

A. The device of the combination lever is employed in the Walschaerts gear to produce the secondary motion of the valve by which it is advanced to overcome the delay in its movement due to the lap, and also to give the port opening for lead when such is desired; and to do this is the sole function of the combination lever. While in either type of gear the motion of the piston must eventually furnish every motion of the valve. The Stephenson plan must change the straight-line motion derived from the piston into the circular motion of the wheel and axle, and back again to the straight-line motion of the valve for each of its several functions, and this introduces errors impossible to entirely overcome. The Walschaerts gear, however, takes the straight-line motion of the piston right at the cross-head and, through the combination lever, as noted in answer to question 7, a short, diverting motion is imparted to the valve-stem that most accurately shifts the position of the valve the required amount for lead.

Q. 19. Then, if an engine with the Walschaerts gear was standing with crank-pin on the forward dead center, with cylinder cocks open, and the throttle should be opened if no steam should blow from the forward cylinder cock it would prove that this engine had no lead to the front admission port, would it not? And if the valve gear was correctly set up, would not the one foregoing test prove the amount of or absence of lead to the back admission port as well? And would not such test have the same result if made with the crank on either dead center?

A. Yes to each question, because the combination lever gives exactly equal results at the finish of each stroke of the piston.

Q. 20. And if an engine standing as suggested in question 19 should prove to have no lead because no steam blew from the cylinder cock, would it still be necessary for a combination lever to be used?

A. Yes. In the Walschaerts gear the combination lever is a necessity whenever the valve has any steam lap, and all locomotive valves have.

Q. 21. Does the amount of lead supplied by the Walschaerts gear remain the same at all points of the cut-off?

A. Yes; the lead is permanent for all points of cut-off, does not change, and can not be changed.

Q. 22. In the Stephenson link motion does the lead vary?

A. It does. The position of each eccentric is adjusted on the axle to a certain amount of lead when in full gear, but as the reverse lever is hooked up toward the center the lead increases in amount.

Q. 23. Are there not different ideas held concerning the real meaning of the term "lead"?

A. Yes. Many enginemen refer to the shift in position of the Stephenson eccentrics, or the presence of the Walschaerts combination lever, as simply for the purpose of securing lead, when, as explained, the valve may be set blind—without lead—yet still the valve should not be centered with the crank-pin on a dead center.

Q. 24. How may it be known from outward appearance whether with the Walschaert gear a piston valve is of inside or outside admission?

A. This depends upon the individual design of the reversing gear principally, but in the strictly American style of construction, whereby the radius rod is lowered when the reverse lever is thrown forward and raised by throwing it back, and assuming an engine to be run-

ning forward, for the sake of distinction, with outside admission valves of either the D-slide or piston type, the eccentric is located 90 degrees ahead of the main crank-pin, and the valve-stem is connected to the upper end of the combination lever, with the radius rod connection to the combination lever beneath it; with inside admission valves the eccentric is located 90 degrees behind the crank-pin, and the radius rod is connected to the upper end of the combination lever with the valve-stem connection beneath it.

Q. 25. Illustrate this principle.

A. Note Figure 2, the Mallet Articulated Compound Locomotive built by the American Locomotive Company. Remembering the information given in the answer to the last preceding question, it will be seen that the forward "engine" has a D-slide valve—necessarily of outside admission—with the valve-stem connected to the combination lever above the radius rod, and the eccentric set a "quarter" ahead of the main crank-pin. The rearward engine has piston valves, and we may know that they are of inside admission by reason of the location of the eccentric in its relation to the crank-pin, and the connections of valve-stem and radius rod to the combination lever being opposite to the arrangements of those parts on the forward engine.

Q. 26. In referring to "shorter cut-off," and "hooking-up," do not both expressions mean the same?

A. "Shorter cut-off" is an effect with "hooking-up" as the cause. With the Walschaerts gear, if the reverse should be set in either extreme end notch of the quadrant, it will cause the radius rod to be carried at either the extreme upper or lower end of the link, thus giving the valve its longest travel and admitting steam to the cylin-

der during the greater part of the piston's stroke. Hooking up means changing the position of the reverse lever to a notch nearer the center of the quadrant in either forward or back gear, and as this brings the radius rod and link-block correspondingly nearer to the center of the link, a shorter motion is imparted to the valve, and the admission of steam to the cylinder and the exhaust therefrom are cut off—cease—at earlier periods in the course of the piston's stroke. Hence the expression of "shorter cut-off."

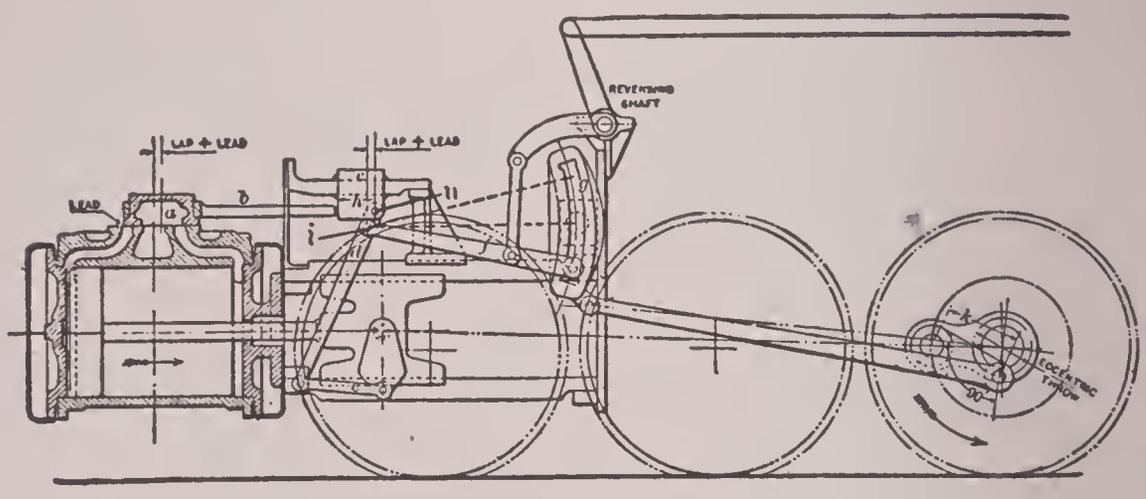


Fig. 3. Walschaerts Motion with D-Slide Valve.

Q. 27. Using a diagram in side elevation, give a description of the operation of the Walschaerts gear in connection with a valve of outside admission during the course of one single stroke of the piston.

A. With reference to Fig. 3—a Baldwin engine with the Walschaerts gear and outside admission valves of the D-slide pattern—the crank-pins are on the front dead center and piston at the extreme forward end of the cylinder just ready to begin its backward stroke. In referring to the positions of the crank-pin and single eccentric and their relations toward each other, it must be

remembered that we assume the engine to be running forward, always; in Fig. 3, then, the eccentric is a "quarter" or one-fourth turn ahead of the crank-pin as the wheel turns forward, which is as it should be with outside admission valves. The eccentric, being now on a vertical line through the center of the wheel, holds the link in a vertical position and if the reverse lever was moved from the forward notch, where it now stands, clear over to the farthest back-up notch, it would raise the back end of the radius rod and link-block from the lower to the upper end of the link, and the radius rod would assume in turn the different angles represented by the dotted lines, but the position of its forward end would not be altered the slightest because the link curves toward the fulcrum of the radius rod, and its radius is the same as the length of the radius rod; in other words, the curve of the link is the same as if it was a section of the rim of a wheel of which the radius rod is a spoke with the pin in its forward end as the hub center. When the eccentric is just 90 degrees from the crank-pin the valve will be exactly centered on its seat if there should be no other device employed for advancing it to secure lead; the combination lever is introduced for that purpose, but let us remove it and note the result: Imagine that we remove the pin from the lower end of the combination lever, thus disconnecting it from the cross-head, and draw it to the right; the pin, *i*, will remain fixed in position and fulcrum the motion of the combination lever, the upper end of which will move to the left with its slide from which it is suspended; this slide is connected to the end of the valve-stem, acting as a cross-head for it, and when the combination lever has been drawn to a vertical position—proven by the pins *i* and *n* near its upper end, being on

the same vertical line—the valve will be placed at the true center of its travel with both steam ports overcovered by the amount of outside lap. Now we will take out pins *i* and *n*, thus entirely disconnecting the combination lever, and we find that by raising the front end of the radius rod its pin hole, *i*, will just match in position with the pin hole *n* in the valve-stem slide so we will insert a pin to join them, and having the radius rod and valve-stem thus directly connected together, there is a direct and unbroken line of motion from the link-block to the valve; as the crank-pin stands, on a dead center, the valve would be at its center of motion and we have an engine that would run, but in which the piston would not begin to exert its power until it had been carried some distance in its stroke; but the maximum force of the piston would be exerted at the time when the crank was exerting its greatest leverage.

The plate shows a vertical line drawn through the center of the cylinder and valve seat, and a similar line through the exact center of the valve, and taking this engine as it stands, except for the change made by removing the combination lever, those two vertical lines would exactly coincide; the valve has no advance whatever—the lap is positive—and in replacing the combination lever the method of producing lead will be demonstrated.

The engine is shown with the main rod removed, so as it will not affect the crank we will push the cross-head back until the piston is at the center of the cylinder—on the vertical line drawn through it—and we can then reconnect the combination lever without changing the position of the valve, because the piston and valve are both centered, and when that condition exists the com-

bination lever is vertical, in regard to its upper two connections. After the radius rod and valve-stem have been disconnected from each other and reconnected to the combination lever, we will push the cross-head forward again, and as it advances the valve will be pulled in the opposite direction by the angle which the combination lever is assuming until when the piston has reached the finish of its forward stroke we find that the valve has uncovered the front admission port by a very slight amount for the lead opening, and it has been done without any movement of the eccentric or link, showing that the position of the eccentric has nothing to do with the lead. Vertical lines through the two pins of the combination lever conecting it with the radius rod and valve-stem are now exactly the same distance apart as are the parallel lines through the valve and seat, showing that the amount of advance given to the valve when the crank is on the dead center is governed by the angle assumed by the combination lever at that time, and its length between the upper pins connecting it with the radius rod and valve-stem, for the distance between the vertical lines through valve and seat, and through the pins of the combination lever is exactly equal to the length of the lap of the valve plus the lead.

When we had the combination lever standing vertically and the valve and piston at the centers of their travels, if we had drawn the cross-head backward to the end of its stroke the back admission port would have been uncovered for lead, and the valve would have been off center exactly the same distance as shown in the plate, but in the opposite direction.

The position of the reverse lever would have had no effect on the valve movements that we have been sup-

posing, for with the eccentric directly below or above the center of the wheel, the link will be held in a position in which the link-block can travel from one end of the link slot to the other without changing the location of the front end of the radius rod.

Let us assume that the main rod is coupled up. We will place the reverse lever in the center notch of the quadrant and this brings the radius rod up to the horizontal position shown in dotted line, and the link-block pin will coincide with the fulcrum pin, or trunnion, at the center of the link, and from which it is suspended; now, if the engine should be pushed, or its wheels made to revolve in either direction, the eccentric would give the full motion to the link—which it does regardless of the position in which the reverse lever is carried—but the link-block being at the center of the link is given no motion, and therefore it imparts none through the radius rod to the combination lever and valve. The valve will be given its short travel, however, received from the cross-head, and always in the opposite direction to the piston's travel. Whether the wheels turn forward or backward the result is the same. As the piston reaches either end of the cylinder the combination lever has drawn the valve just far enough in the opposite direction to uncover the admission port the requisite distance for lead.

Now drop the reverse lever ahead, and, with the gear as shown in Fig. 3, with the addition of having the main rod up in position, which we will assume, we start the engine forward under her own steam; the starting, however, must be done by the piston on the other side of the engine, for the admission of steam to the visible cylinder can exert no turning power to the wheels while the crank-

pin is on the center; as the crank leaves the front center its motion is downward, rather than backward, and the straight-line motion of the cross-head and piston will be to move backward very slowly at this time, with a consequent delay in the motion of the lower end of the combination lever. Just at this time, though, the eccentric is making its quickest move, the lower end of the link is carried backward, drawing the upper end of the combination lever, and if the valve—practically a straight line of motion, and the fast motion of the eccentric is imparted to the valve, thus giving the forward admission port a quick, full opening at just the time the piston has started to enter, what should be the most effective part of its stroke—when the crank-pin is nearing the "quarter." The starting angle of the combination lever is maintained until the piston has made about one-fourth of its stroke, when at that time the crank-pin is starting on the fastest part of its circular path of motion—past the quarter—and the motion of the lower end of the combination lever is accelerated while its upper end is retarded by the delay of the eccentric in approaching and passing the end of its backward stroke; this causes the combination lever to begin straightening up toward a vertical position, and as its motion lessens with its angle the valve stops and slowly begins a forward movement, traveling faster as the eccentric gets well started on its forward stroke, and after the crank-pin has passed the lower quarter of the combination lever begins to incline itself over in a position opposite to that in the plate. As the crank-pin finally approaches the end of its single stroke —the back center—the eccentric will be moving rapidly forward toward its "upper quarter," which, in connection with the fast increasing angle of the combination lever,

gives such a quickening forward motion to the valve that after the steam has been cut off from the forward admission port its opening to the exhaust and the lead opening to the back admission port follow in most rapid sequence. Thus, at the completion of a single stroke of the piston all parts of the motion work will be in positions exactly opposite to those shown in Fig. 3, except that the link will have returned to the same position as in the plate, for the eccentric will again be on a vertical line through the center of the axle, although above, instead of below, the center.

Q. 28. Without detail, and in fewer words, simply relate the changes occurring in the Walschaerts valve gear during a stroke of the piston.

A. On the front center the gear is as shown in Fig. 3; with the crank on back center the eccentric is nearly raised from below to above the hub center without any change in the point of location of the forward end of the eccentric rod, nor link; the location of the piston being changed from the front to the back end of the cylinder, the cross-head has carried the lower end of the combination lever the same distance back of its vertical line that the plate shows it ahead of that line, with the result that the upper end of the lever will be thrown the same distance ahead of its central perpendicular that the plate shows it back of that line, thus moving the valve forward of the central position in which the eccentric has placed it, the same distance that the plate shows it back of that position, and this will give precisely the same amount of lead opening to the back admission port that the plate shows is given to the forward port.

Q. 29. The Stephenson link motion may be either "direct" or "indirect." How about the Walschaerts gear in this respect?

A. The Walschaerts gear is of direct motion when the reverse lever is forward of the central notch of the quadrant and the radius rod below the center of the link, for there is then a direct, or unreversed, line of motion from eccentric to valve, the link acting as a single-arm rocker; it is of indirect motion with the reverse lever in any back-up notch, as then the radius rod is carried above the link center and the motion produced by the eccentric and transmitted to the lower end of the link by the eccentric rod is reversed by the oscillation of the link, and the motion it delivers to the radius rod and valve is in an opposite direction, therefore, to that received from the eccentric, the link in the latter case acting as a double-arm rocker.

Q. 30. Will the eccentric of the Walschaerts gear give any movement to the valve when the engine is running if the reverse lever is standing in the center notch of the quadrant?

A. No, for then the radius rod is being carried at the center of the link and will receive no motion; but the valve will have the short travel derived from the crosshead, through the combination lever, a travel equal to twice the length of the valve's lap and lead added together. The pin in the forward end of the radius rod at this time acts as a fixed fulcrum to the combination lever which is receiving no motion except from the crosshead.

Q. 31. When the reverse lever is forward of the center of the quadrant the radius rod is working in the lower half of the link, and with the lever back of the center the radius rod is in the upper half of the link—is it not?

A. Such is common American practice, but if it will simplify the reversing gear the radius rod may work

above the link center in the forward motion, and many European engines with Walschaerts gear are so designed. Fig. 4 is a reproduction of such construction from Auchincloss' book on Valve Motion, and represents an engine running forward; the reversing—or tumbling—shaft is located, as with old-time Rogers engines, below the link, thus lessening the "slip" of the link-block while it is working in the upper half of the link, which is forward gear in this case. It will be noted from the plate that the

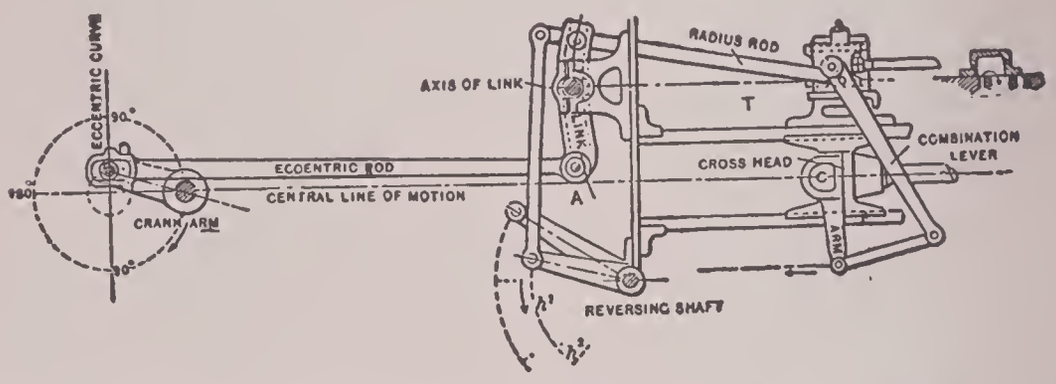


Fig. 4. Walschaerts motion with Radius Rod above Link Center in Forward Gear.

only other alteration in the gear made necessary in changing the position of the radius rod to the opposite end of the link is simply to change the location of the eccentric from 90 degrees ahead of the crank-pin to 90 degrees behind it, with outside admission valves as in the plate, or vice versa with valves of inside admission. Of course the reversing gear must be designed so that the reverse lever will be forward of the center notch of the quadrant when it has raised the radius rod above the link center.

Q. 32. Is it easier to secure equal cut-off of the admission of steam to each end of the cylinder with the Walschaerts gear than with the Stephenson link motion?

A. Yes; in the Walschaerts gear the opening and closing moments of the ports are accomplished with equal precision in each direction of the valve's travel and can not be otherwise, for, as the piston moves in either direction from the center of the cylinder it causes the combination lever to move the valve in an opposite direction with outside admission, and in the same direction with inside admission valves of the piston type, but in either case the distance the valve is moved exactly equals a certain and fixed proportion of the distance of the piston's travel, this being the leverage proportions of the combination lever.

Q. 33. The curve of the Stephenson link is from a backward radius. Why is the curve of the Walschaerts link on a radius from ahead?

A. As the radius rod, by its attachment to the link-block, may be carried at any point in the link according to the direction of motion and the point of cut-off, raising or lowering the radius rod from the center would put it at an untrue angle with the link if the curve of the link were not toward the radius rod and of a radius equal to the length of the radius rod from its pin connection with the combination lever to the link-block pin. Setting the engine on either dead center—as in Fig. 3, for instance—the reverse lever may be brought from one end of its sector clear over to the farthest opposite notch without shifting the position of the valve in the slightest degree if all parts of the motion work have been correctly designed and properly set up, for, while the link-block is being moved from one end of the link slot to the other it is at all times equidistant from a fixed point represented by the location of the pin connecting the radius rod and combination lever when the radius rod is at the center of the

link; to enable this to occur, the radius and direction of curve of the link must conform to the radius rod; and it is called the radius rod because its length determines the radius of the link's curvature.

Q. 34. Describe the Walschaerts link in detail.

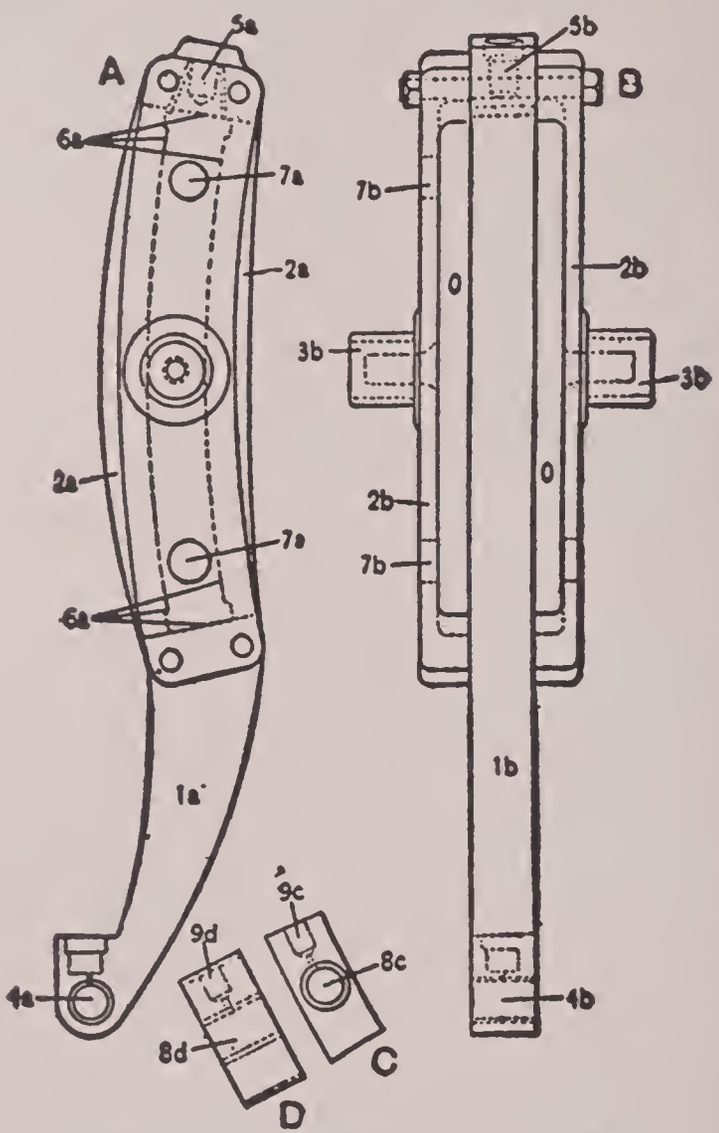


Fig. 5. The Walschaerts Link.

A. The reversing links used in connection with the Walschaerts gear by different engine builders, and on locomotives of different types, vary somewhat in design; some are open links nearly like those of the Stephenson link motion, but generally they are very similar to the one

illustrated in Fig. 5, which is engraved from a blue-print furnished by the American Locomotive Company.

The piece that forms the link proper, and has the slot that holds the link-block, is extended down much further than the slot in order to take the eccentric rod connection as near as possible to the horizontal line through the wheel's center, this lower extension forming the link foot; the link piece is shown in side elevation *A* as *1a,* and in end view *B* as *1b;* it is forged from wrought iron and case-hardened. The frame that carries the link piece is composed of the two bracket pieces *2b,* in view *B,* one on each side, with their ends bolted to the link piece; they are of cast steel, each including the fulcrum pin *3b* by which the link is suspended and which are designed to be even with the center of the link slot, both vertically and horizontally; a case-hardened bushing of wrought iron is pressed on to these link trunnions, or fulcrum pins, in order to prevent any lost motion from wear. The pin hole in the link foot, *4a, 4b,* to which the eccentric rod is connected, is also fitted with a wrought iron, case-hardened bushing. In view *A,* the slot in the link piece in which the link-block operates is in dotted outline as indicated by *6a, 6a,* and the link-block is shown in the views *C* and *D; C* is the side of the block and as it would appear if raised to its position in the link slot in the view *A,* and the edge of the block is shown in view *D* as it would lie in the link turned to the endwise view *B,* and when in place in the slot the sides of the block are almost flush with the sides of the link piece to afford room for the jaws of the radius rod to pass inside of the brackets; the hole *8c, 8d,* is for the pin by which the radius rod is attached to the link-block, and this hole, like the others, is also bushed with case-hardened wrought iron.

A plan of the gear would show the radius rod lying on the same longitudinal line as the link; the back end of the radius rod is forked, a jaw passing on each side of the link piece and inside of the carrying bracket piece, the jaws embracing the link-block; there is a pin hole through each jaw of the radius rod coinciding with hole *8c, 8d,* of the link-block for the pin that connects them together, and these holes are bushed similiarly to the other pin holes as described; but there will be no wear to the pin holes through the radius rod jaws for the reason that a keying bolt runs down through a vertical hole in each jaw and through the link-block-pin, thus holding the pin rigid with the radius rod, the pin turning only in the hole through the link-block. The openings at *7a, 7b,* in the outer link bracket piece besides providing means for direct oiling of the bearing surfaces of link-block and link may also be used as an aperture through which the link-block pin can be removed.

The link piece contains an oil well, *5a, 5b,* in the top end, and another similar one, *4a, 4b,* in the link-foot, each with a small feed hole drilled out at the bottom and the top ends threaded to take a screw cap nut, for continuous lubrication of the faces of the link-block and eccentric rod pin. An oil well of the same kind is also provided in the top of the link-block, to lubricate the radius rod pin.

It is by reason of the connection pins working in holes that are fitted with practically non-wearing bushings, easy to oil, that no lost motion of any moment develops in the Walschaerts valve gear.

Q. 35. Is the eccentric rod always connected directly with the link foot?

A. No, but it must have the same effect. Sometimes the valve chest lies so far in toward the center line of the

engine that the link, to be in line, is also too far in for direct connection with the eccentric rod, and in such cases it is common for the link to have a supporting and carrying fulcrum pin on but one side—the outer side—and this fulcrum pin attached to the outer link bracket is lengthened to form a shaft working in a journal-box, and extended outward far enough to have an arm attached to it in line with the eccentric rod; this arm reaches down as much farther than the lower end of the link as the link foot would extend, for the connection of the eccentric rod. When this method of connecting the eccentric rod with the link is employed there is, of course, no link foot, the link having exactly the same lengths above and below its central trunnion.

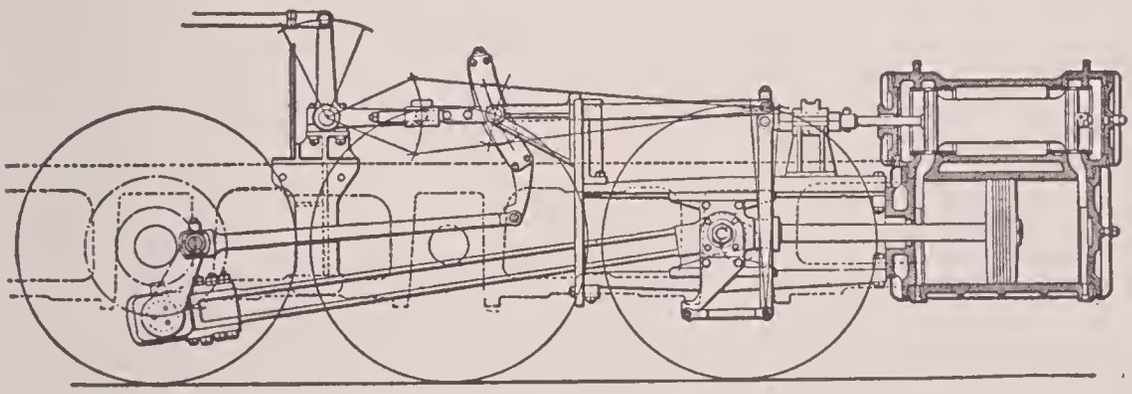


Fig. 6. Walschaerts Gear with Piston Valves of Inside Admission.

Q. 36. The action of the Walschaerts gear in supplying the motion to a valve of outside admission has been explained in answer to Question 27, and with reference to Fig. 3. Now explain the difference in the set-up and operation of the gear as applied to an engine with valves of inside admission.

A. Fig. 6 represents the latter type—piston valve of inside admission; the reverse lever being in the center notch of the quadrant, the radius rod is in position at the

exact center of the link just the same as though the valve were of outside admission, and this places the upper end of the combination lever—to which the radius rod is connected—at its point of mid-throw, while the piston being precisely in the center of the cylinder its cross-head fixes the lower end of the combination lever at its point of mid-travel, and these combined influences give the combination lever a position which is plumb perpendicular, both its upper pin holes—the radius rod and valve-stem connections—are on the same vertical line, and this results in the valve being placed exactly central on its seat with both admission ports over-covered by the amount of steam lap, and this lap is from the inside faces of the valve pistons in this case, because the live boiler steam is contained between the pistons. With an engine standing as in Fig. 6 the position and location of combination lever and valve would be the same with valves of either inside or outside admission.

Rotate the wheels one-quarter turn backward to bring the piston at the front end of the cylinder, and the rise of the eccentric to top quarter would pull the link to a vertical position, but have no effect on the radius rod nor upper end of the combination lever, but the lower end of the lever would be pulled forward carrying the valve-stem in the same direction as the piston's travel and moving the valve forward of its central position, as shown in the plate, far enough to overcome the lap and to open the front admission port by the amount required for lead, from the inside of the front valve piston.

Fig. 6 most clearly illustrates the method of securing lead in the Walschaerts motion; as the engine stands just imagine that the main rod is removed, and then by pushing the cross-head to each end of its stroke, in turn, the

valve's established amount of advance for lead is thereby produced, and proven to be equal at each end of the cylinder.

While a valve of outside admission must be thrown by the combination lever in an opposite direction to the stroke of the piston to secure lead, this valve of inside admission must be advanced in the same direction as the piston's stroke for that purpose and to produce the effect the valve-stem is connected to the combination lever below the radius rod connection. And as the valve of inside admission must have its long travel derived from the eccentric to be in an opposite direction to the travel of a valve of outside admission, the eccentric is located so as to follow the crank-pin by a quarter-turn, as shown in the plate, instead of leading the crank by that distance as with valves of outside admission.

Although the piston in Fig. 6 is at the exact center of the cylinder the crank-pin has not yet completed one-half of its travel between the dead centers—assuming the engine to be running forward; but if the back end of the main rod could be disconnected and raised the circular opening in its stub-end would center evenly with the hub center, showing that it has gone half way in a straight line of motion, but in dropping it again to its depicted position the back end of the rod describes the arc of a circle which carries it to a point a few degrees forward of a vertical line through the hub center, and the shorter the main rod the greater the variation from the center line. As the eccentric is placed, theoretically, 90 degrees from the crank-pin, this angularity of the main rod in offsetting the pin from the true quarter also affects the position of the eccentric, giving it now a location a few degrees away from, and higher than, its horizontal center

line of motion, but as this error of location is at right angles to the eccentric rod the effect of this slight offset is not perceptible in operation, for, as the engine stands, the error is present and if the reverse lever should be thrown into either gear it would have to go to the corner notch to receive the full effect of any error from the source referred to, and with the radius rod at either end of the link an admission port would be opened to its full capacity, admitting no error of such slight moment; so the angularity of the main rod can exert no mischievous influence in the Walschaerts gear.

From Fig. 6 it has been shown how the lead is produced by simply moving the cross-head to the finish of either stroke for the short travel of the valve, and that by placing the reverse lever in either corner notch the long travel of the valve is given; both ends of the link slot are at an equal distance from a vertical line through the link fulcrum so that whether the radius rod is raised or lowered it will throw the upper end of the combination lever an exactly equal distance either forward or back of its present central position, completing the full travel of the valve either forward or back.

Q. 37. Does the length of the radius rod hanger, and the location of its point of suspension, have any material effect on the action of the Walschaerts gear?

A. It does, to a remarkable degree. There is but one correct location for the point of suspension, and that point can only be determined by an expert designer of the gear, and any variation from the true locus will introduce serious error in the motion. As to the length of the suspension bar, that also has considerable influence on the action, but there is a variance of opinion as to the length of suspension bar that should give more nearly correct

results. On one of the earlier Mason engines the suspension bar extended from the radius rod to a lifting arm on a reversing shaft that was carried across the top of the boiler, while in a much later design of the Walschaerts gear by the same builders the height of suspension above the radius rod was only equal to one-half the length of the link. The former was an extreme case, but the latter was not if we notice the manner of radius rod carriage in Fig. 6, a design of the American Locomotive Company, where there is no swing suspension to the radius rod at all. On the end of the lifting arm there is a pivoted slide through which the end of the radius rod extends, beyond the link, and the reversing shaft is located on the same horizontal line as the link trunnion, or fulcrum pin.

Q. 38. Does the Walschaerts gear admit of experimental changes or readjustments in the roundhouse or on the road, such as seem to be required with the common link motion?

A. No; there is no portion of the Walschaerts gear that can be lengthened or shortened, outside of the general repair shop, nor will there be any necessity for alterations in the motion work. Formerly it was the practice to fit the Walschaerts eccentric rod with screw adjustments in order to correct through it any little variation in the proportions of other parts of the gear or slight errors in fixing the location of permanent positions of the gear forward of the eccentric. Such a screw take-up is impractical with the very heavy rods now used, but its length may be slightly changed by adjusting the bearings at the eccentric end on some engines. Even were it possible to do so no change should ever be made in the motion work of this gear ahead of the eccentric rod except in the "back shop."

Q. 39. Does lost, or slack, motion appear in the Walschaerts gear from wear at the connections or other sources as rapidly as it does in the Stephenson gear?

A. No; and one of the greatest recommendations for the Walschaerts gear is the almost entire absence of slack due to wearing away of the bearing parts, thus insuring continuous regularity in the distribution of steam to the cylinders. Under ordinary conditions an engine will run from shopping to shopping without having had any part of the Walschaerts gear closed on account of worn looseness, and the engine will re-enter the shop with the valve gear cutting off the steam, often, with no perceptible loss in economy; this is largely due to the fact that all connections are made with pins working in bushings, all case-hardened, and no large eccentrics with the enormous frictional surfaces of their sheave and strap.

Q. 40. The Walschaerts eccentric is always referred to as being located 90 degrees from the main crank-pin. Is this correct?

A. Actually measured in degrees the Walschaerts eccentric will usually be found to be located somewhat nearer to the crank-pin than the nominal 90 degrees when outside admission valves are used, and an engine with exactly the same set-up of gear except in having inside admission valves would have the eccentric placed just the same number of degrees more than 90 away from the crank-pin.

It must be remembered that the link is so centered with the valve as to impart to it a motion free from the result of incorrect angles, and in order to obtain that result the link is hung so high that there is an undesirable angle in the transmission of motion from the eccentric

to the link. The ideally correct design of the Walschaerts gear locates the connection of eccentric rod to link exactly on the center line through the axle, and when so placed in actual construction the eccentric will be located exactly 90 degrees from the crank-pin; but, as explained, this location is not commonly obtained on modern locomotives; if the link foot was extended down to receive the eccentric rod connection at the theoretically correct location its length would shorten the throw of the link to an impossible extent, so a compromise is effected; the link foot is extended as low as may be permissible, and to correct the error still existing, due to the angularity of the eccentric rod's position, the location of the eccentric is slightly shifted in the indicated direction.

Noting closely Fig. 3, it will be seen that while the crank-pin is on the exact front center the eccentric is on a wheel radius that is at right angles, or 90 degrees, to a line from the link foot pin to axle center, the curved arrow indicating that the eccentric is located 90 degrees from the center line of motion of the eccentric rod; and when that line happens to coincide with the main rod's center line of motion—then, only, the eccentric will be 90 degrees from the crank-pin.

If an inside admission valve was substituted for the D-slide valve in Fig. 3, the eccentric would have to be changed to a location directly opposite, across the hub—180 degrees distant, around—and it is plainly seen that in moving across on the radial line of the eccentric, that would place it just the same number of degrees more than 90 away from the crank-pin—above the wheel hub—that it now is less than 90 degrees from the crank-pin.

Q. 41. While an engine is running the bounding up

and down due to the spring action affects the proper working of the Stephenson gear, causing imperfect steam distribution. What effect does the rough carriage of the engine have on the Walschaerts gear?

A. It has no discernible effect, and when the link is set low enough that with the crank-pin on the dead center the pin connecting the eccentric rod with the link foot will be on the horizontal center line through the axle—its theoretically correct location—the rise and fall of the engine will then have absolutely no effect on the motion imparted to the valve.

Q. 42. By reason of the return crank projecting the Walschaerts eccentric out and further from the driving-box than the Stephenson eccentrics are usually placed, is it not the case that lost motion in the driving boxes will introduce greater irregularities in the action of the Walschaerts valve gear?

A. Not at all; for, while the Walschaerts eccentric may be deflected slightly further than those of the Stephenson type, lost motion in the boxes is largely dissipated by the very great lever length between the suspension pins of the link and the eccentric rod connection with the link foot, and through which any motion engendered by the eccentric is reduced by a certain and considerable proportion when transmitted to the radius rod and valve. Loose driving-boxes should not be permitted, however, as the general effectiveness of an engine with any style of valve gear is seriously impaired when the driving-boxes are in such condition that setting-up the wedges will not remove the lost motion at those points.

Q. 43. Do the connections or other bearing parts of the Walschaerts gear have a tendency to heat in service?

A. No. This valve gear is peculiarly free from any disposition toward heating; there have been certain cases where it has not been designed to meet the unusual conditions of track and service, and the eccentric rod pins have heated on account of the twisting effect, on rough track, between the parts carried by the driving wheel and the parts carried by the main frame. Such troubles are not constitutional, are easily cured and never need to have existed.

Q. 44. In connection with the Walschaerts gear, how may the valve be exactly centered upon its seat so that with open throttle steam will not blow from the open cylinder cocks?

A. With valves of either inside or outside admission, when the cross-head is at the exact center of its travel with crank-pin on the upper or lower working quarter, reverse lever in center notch of the quadrant and the combination lever standing—as it must—in a plumb, vertical position, its two upper connection pins on the same vertical line—then the valve is at the perfect center.

Q. 45. What is the meaning of the above reference to the crank-pin as being on the "working quarter"?

A. As explained in answer to a previous question, when the crank-pin is on the perfect quarter it is on a vertical line through the hub center, either above or below it, but owing to the angularity of the main rod the piston is not then at the exact center of its stroke; but when the piston is at the true center of the cylinder—as outwardly indicated by the cross-head lying at the center of its travel in the guides—the crank-pin is then a few degrees forward of the true quarter, but is usually referred to as being on the quarter at that time—therefore

the working quarter. This difference sometimes causes confusion, and in alluding to the placing of an engine "on the quarter" it should be stated whether the quarter is to be fixed in reference to the position of the cross-head or crank-pin.

Q. 46. If an engine with the Walschaerts gear is standing on the working quarter, the piston at the exact center of the cylinder and the reverse lever in the center notch of the quadrant, suppose that the valve was not truly centered—steam would blow from one of the cylinder cocks with the throttle open. What would be the cause, and how could the cause be detected and remedied?

A. With the gear in this position there would have to be an extensive error indeed to allow steam to blow from a cylinder cock, as this would indicate a false movement of the valve more than equaling the length of its lap, and might be caused by a piston valve loose on the stem, or a broken yoke with a slide valve. However, if error is indicated in the position of the valve, first be sure that the reverse lever is in the center notch; if the notch is indicated there may have been a mistake in laying-out the notches or in setting-up the quadrant, but if the link trunnion and link-block pin coincide exactly that is what we want and the reverse lever is centered all right, and in that case if the piston is also truly centered and the valve is not, probably the link bearer, which is commonly attached to the guides, varies a little in its position, fore or aft, and should be moved far enough to correct the error; or the valve-stem can be lengthened or shortened, but as this induces other minor errors the other method would be preferable.

Q. 47. If the link bearer should be moved, thus shifting the fulcrum of the link, would not other variations in the gear be introduced thereby?

A. The resetting of the link fulcrum might be just what was needed to perfect the whole valve motion if it had been set up untrue; but it might be that while adjusting the location of the link fulcrum would square the valve, by the radius rod at the link center, with the reverse lever in a working notch, there would be unequal cut-off by the valve still, for the difference made by this change would have to be borne by the eccentric rod and to finally true-up the motion it might have to be lengthened or shortened as required.

Q. 48. Give directions for adjusting the length of the eccentric.

A. Set the engine with the crank-pins on the forward dead center, and have the reverse lever moved from the corner notch in forward gear up to the center of the quadrant, and if the valve-stem is moved forward at all while the radius rod is rising the eccentric rod should be lengthened; or, if the valve-stem is drawn backward as the radius rod is guided upward by the link the eccentric rod needs shortening. In either case, of course, the alteration should be by degrees, each one very slight and tests constantly repeated, until drawing the reverse lever from the corner up to the center notch will impart no movement whatever to the combination lever and the valve stem. For a general test, try in the same manner and alter if necessary the eccentric rod on the other side of the engine, but starting the test with the crank-pin on the back dead center.

It is a fundamental principle of the Walschaerts gear that the motion work forward of the link, including the link bearer, is permanently set up and supported by rigid attachments to the guides, guide-yoke and cylinder casting; the eccentric rod, however, represents the unstable

distance between the rigidly carried gear and the main driving wheel, and as this distance will vary from wear in the driving-boxes, the length of the eccentric rod should be tested as directed, occasionally, and if necessary, shortened or lengthened.

Q. 49. Why is it so important that the Walschaerts motion work should be supported by attachments in rigid connection with the cylinder casting?

A. Any style of valve motion is designed to simply furnish a sort of reciprocating action between the piston and the valve; both work in practically the same body casting and are in permanent alignment, and the motion of one will be transmitted without error to the other if the associated arrangement of gear that develops the transmission is solidly attached to the body occupied by the piston and valve; in the common erection of the Walschaerts gear the motion work is borne at but three supporting points—the link fulcrum, the reversing shaft and the valve-stem slide; the first two are carried on brackets attached to the guide bearer, or yoke, and the valve-stem slide is either mounted on the upper guide-bar or the slide-bar is connected to the cylinder body at one end and to the guide yoke at the other. Therefore the accuracy of the Walschaerts gear is not affected by the roll and twisting effect of an engine in motion.

Q. 50. Besides furnishing a practically perfect locomotive valve motion, is not the Walschaerts gear more desirable in other ways?

A. Yes, in many ways; the absence of heating is a great feature, and as the whole motion work is outside of the engine frame a chance for perfect inspection is furnished, every part can be easily and economically oiled, and in case of breakdowns in the gear repairs can be most

quickly made, as there will be no necessity for getting under the engine; and the removal of the gear from inside the frame offers a fine opportunity for better frame bracing, and at the point where most needed on the large engines now in service.

Q. 51. When an engine equipped with the Walschaerts gear becomes disabled on one side while on the road, is there any considerable difference in the methods employed in getting the engine in condition to proceed than if the Stephenson motion was employed?

A. A great deal of difference. Enough to make it worth while taking up the several points of possible derangement. Some details are the same, however, in all cases—blocking the valve, for instance, may be done in the same way whenever necessary, and in the same way whether either type of valve gear is used, etc., and while a breakdown in the Stephenson motion work is quite common it doesn't frequently happen to the Walschaerts gear, and engine failures are seldom charged to that account, but when a breakdown does occur repairs can be much quicker made to the Walschaerts gear, exposed as it is, outside the frame.

Q. 52. "Blocking the valve" has been mentioned; what is meant, and when and how should it be done?

A. In almost every case of an engine becoming disabled so that the cylinder power can not be used on one side, if the engine is to proceed under her own steam by the power of the other side the valve on the disabled side should be placed in an exactly central position on its seat; the words exactly central position are to be taken literally, for it is not only to have both admission ports covered so that no steam can enter the cylinder, but because in that position both ends of the cylinder will be

in communication with each other through the exhaust cavity of the slide-valve, or through the passage in the spool of the piston valve of inside admission—this, of course, with valves having exhaust lead, as most of them now do have, and this external exhaust communication is plainly shown in Fig. 6, as the valve stands.

After the necessary disconnections of the motive and valve gear have been made the valve on the disabled side of the engine must be centered by moving on the valve-stem and judging from its travel when correctly centered; a better way, with the Walschaerts gear, however, is if the radius rod is not damaged have it placed at the center of the link—by putting the reverse lever in its center notch if possible—and then fixing the combination lever in its central position so that its two upper connection pins are on a vertical line with each other; the valve will then be exactly centered and the way is exemplified in Fig. 6.

After it is seen that no steam will blow from the opened cylinder cocks on the broken-down side with the throttle slightly opened, however, the valve is practically centered, but in any case it is best to disconnect the cylinder cock rigging on that side so that the cocks can be left permanently open and permit those on the other side to be worked at will, in order to afford relief against compression in the cylinder from the travel of the piston if the main rod is left up, in place, and also for detection in case the valve should get shifted off center by showing steam at one of the cocks; some engineers prefer to unscrew and remove the cocks entirely. When the cylinder is fitted with plugs for indicator connections their removal will obviate the necessity of disconnecting the cylinder cock rigging.

On many roads a clamp is carried on each engine to secure the valve-stem immovably with and fix the valve on the correct center in case of breakdowns, but where such clamp is not at hand it has been generally the custom to raise the steam-chest cover—where a D-slide valve is concerned—and place retaining blocks in front and behind the valve, wedging them in, and so secure it in position; but it is out of the question to try to raise the cover of the steam-chest on one of our big, modern engines and it is safe enough, under the charge of a watchful, competent engineer, to omit the actual blocking, for, after the valve has been centered, when steam is used its pressure on the unbalanced area of the slide-valve will be great enough to hold it beyond any danger of moving except in case of bumping up against cars, and then the engineer will be warned by the steam from one of the open cylinder cocks. An advantage in not permanently securing the valve is that, where the main rod has not been taken down, if the live side should stop on the dead center the valve on the disabled side could be moved by the stem off center, to open the proper admission port, and steam then used to move the engine just far enough to get the working side off the center, stopping at the right moment with the air brakes, and then with steam shut off the valve can again be centered.

Piston valves of inside admission are perfectly balanced, fore-and-aft, and without blocking will usually remain centered by the pressure of the steam setting out the packing rings against the walls of the valve chest.

In times past engineers have been disciplined for not disconnecting the main rod on the disabled side of the engine and allowing the piston to churn in the cylinder; now, however, the weight of the main rod makes taking

it down on the road prohibitive, and it has been found that no trouble need result from leaving it up if the engineer understands his business; if he does, he will let the lubricator feed to the steam chest on the disabled side as usual and at certain stops, if the valve is not blocked inside the steam chest, he will move it far enough to uncover one of the admission ports (even if not necessary to do so to work the other side off the dead center) and open the throttle slightly to blow the accumulated oil into the cylinder.

Q. 53. With the Stephenson gear when the main rod is left up on the disabled side of an engine its motion can not affect any part of the valve gear, but with the Walschaerts type of gear would it not give impulse to the combination lever, and should not the combination lever then be taken down?

A. Through the cross-head motion would be imparted to the combination lever, but it need not be taken down for its motion should not affect the valve, on account of disconnections made elsewhere in the gear.

Q. 54. Whenever a valve is "blocked" or centered, it must be disconnected, of course, from any part of the gear that would impart motion to it, and with the Stephenson link motion the valve-stem is the general point of disconnection; would that be the recommended practice in connection with the Walschaerts gear?

A. No, it is inconvenient and unnecessary to disconnect the Walschaerts valve-stem—inconvenient, because there is no joint between the valve and the slide that carries the end of the valve-stem, and unnecessary, for the reason that the radius rod must always be disconnected when the valve is blocked, and that removes the fulcruming point of the combination lever. For a lever to trans-

mit motion it must have three points for the reception and transmission of power, and with the radius rod removed the combination lever is left with only the cross-head connection at the lower end and its upper end connected to the valve-stem slide, the latter acting as a fixed suspension point for the pendulum-like swing of the combination lever in unison with the strokes of the piston.

Q. 55. As the disconnection of the radius rod takes the place of, and with the same effect, as disconnecting the valve-stem of the Stephenson link motion, it will be frequently referred to in the following answers to questions relating to breakdowns, and to avoid repetitions explain once for all, in detail, how it should be done.

A. In many cases the radius rod will not need to be removed; where there is but a short distance for the engine to go, or it may be run slowly, remove the pin from point of radius rod and combination lever and raise the front of the rod above any chance of interference with the lever, suspending the front end of the rod by strong rope or wiring of a length that will permit it to swing freely to the motion of the link without striking anything; then just center the valve in the manner already described and proceed slowly. This method, of course, is only to be resorted to where it is merely desired to get to the nearest siding with the engine, which must be run very slowly or the radius rod will kick-off the running-board.

If it is desired to so fix up the disabled side of an engine that she can use the power of the other side to finish the run and make the time with what she can pull in safety, set the reverse lever in the center notch in order to center the link-block, in which position the link can give no motion to the radius rod; then fit a block of wood

within the link slot and under the link-block to support the latter, and disconnect the suspension bar from the radius rod—and also from the lifting arm if it will be in the way of the swing of the link; disconnect the front end of the radius rod from the combination lever and raise and secure it as before mentioned, but with a shorter suspension, as there will be no swing to it now. The slot above the link-block should also be filled in with a piece of wood to prevent the link-block from jumping up from the center and giving a thrust to the radius rod. It is not absolutely necessary to block within the link slot, as wooden pieces may be fitted under and over the radius rod, between its jaws and the ends of the link bracket, but in this case the ends of the pieces that are in contact with the radius rod must be rounded to roll against it as the link swings.

The radius rod having been disconnected from the combination lever, the motion of the lower end of the lever will have no effect on the valve, which may now be centered and secured—or trusted to "stay put" as heretofore explained. As the engine starts to move watch closely the motion of the combination lever during the first revolution of the driving wheels, to see that it does not strike the pin connecting the main rod with the crosshead, as the relative positions assumed by this pin and the combination lever are changed by the removal of the influence of the radius rod.

Q. 56. If the eccentric rod of the Walschaerts gear should break, what should be done?

A. Remove the broken parts, and drop the reverse lever to the go-ahead corner notch; then disconnect the suspension bar from the radius rod on the disabled side of the engine, permitting the link-block to rest at the bot-

tom of the link, and disconnect the radius rod from the combination lever, raising the front end of the radius rod above any chance of interference and securing it there in order to keep the link from swinging. Center the valve in the prescribed manner and proceed.

Q. 57. What should you do in the case of a broken valve-stem?

A. The radius rod should be centered securely in the link, disconnected from hanger and combination lever and wired up at the front end as previously explained; then center the valve in the recommended manner and block, or otherwise secure, the valve-stem slide against any movement on the slide-bar that might be caused by the swing of the combination lever, as it has not the frictional resistance of the valve to hold it in a fixed position, now, but be sure to place the slide at a point where the combination lever will be carried without striking the pin that connects main rod and cross-head.

Q. 58. How would you get along with a case where the radius rod was broken forward of the link?

A. Would remove all parts of the broken rod, disconnecting same from the suspension bar and combination lever, and also from the link-block, unless there was a long enough piece left attached forward of the link to permit of wiring it up and securing the link-block in the center of the link, which could be done in that case. Center the valve in the manner referred to and go on. But under any circumstances in which the radius rod has been disconnected always remember the importance of seeing that the combination lever will swing clear of the wrist-pin in the cross-head, and that the suspension bar will be out of the way of the swing of the link.

Q. 59. If the suspension bar should break, or, where

it is connected to an extension of the radius rod beyond the back of the link if that extension of the radius rod should break, what should be done?

A. In either case place the reverse lever in a notch of the quadrant that will give the valve an average cut-off, or in which it may be continuously worked—forward or back gear, according to the direction in which the engine is to run—raise the radius rod with the broken piece—or hanger—until the link-block is at the same height in the link as the one on the other side of the engine, and insert a piece of wood in the link slot under the link-block to hold it up, and another piece above the link-block to keep it from slipping up. Remove the broken parts and proceed, remembering not to reverse the engine nor to change the reverse lever to another notch.

Q. 60. What should be done in case the combination lever, or the vibrating link that connects it with the cross-head, should be broken?

A. If the combination lever is broken disconnect and remove all pieces that are not in connection with the valve-stem slide; if it be the long arm of the combination lever that is broken, or the vibrating link, take down the vibrating link also, and if the piece of lever remaining attached to the valve-stem slide is long enough to be in the path of the pin in the cross-head, either remove the piece or draw it out of the way and secure it there. Center the valve and disconnect the radius rod, both as heretofore explained, and go on.

Q. 61. In all of the cases so far it has been understood that the main rod has been left in place; suppose, however, that the main rod should be broken, compelling its removal—what ought to be done?

A. After taking down the broken parts of the main

rod and disconnecting the radius rod, if the valve is of inside admission, push it to the forward end of the steam-chest and clamp the valve-stem or block the valve-stem slide to secure it in that position; with a valve of outside admission draw it to the back end of its travel and secure it there; the idea is to hold the forward port open for steam admission against the front of the piston, and the back port open from the opposite side of the piston to the exhaust; the cross-head should then be drawn back until the piston is against the back cylinder head. This is called "steam blocking," for when steam is used it will hold the piston in its fixed position. Then you can go on, but after drifting any distance, shut off, use steam carefully at first for fear the piston may have also drifted forward a little way in the cylinder and will be pounded back to the head too severely; it is better, therefore, to fasten a piece of wood to fit in the guides ahead of the cross-head.

Q. 62. Engines with the Stephenson link motion are totally unfitted to run under their own steam if but one section of side rod should break when it happens that the eccentrics are mounted on a different axle than the one worked directly by the main rod, and if the broken side rod is the one connecting the wheels of the eccentrics' axle with the wheels carrying the main rod on either side of the engine. Could the breaking of any section of side rod, only, have the effect of completely disabling an engine equipped with the Walschaerts valve gear?

A. No; the eccentric of the Walschaerts gear is always mounted on the main pair of wheels—the wheels worked directly by the main rod—and therefore the removal of all sections of side rods on both sides of the engine could in no way affect the valve motion. If, how-

ever, any one section of the side rod should break, the corresponding section or rod on the other side of the engine should be taken down; the only result from doing so will be to make the engine more slippery and very hard to hold to the rail—if equipped with the Walschaerts valve gear.

Q. 63. If the piston should be broken, or loose from the piston rod in the cylinder, what repairs are required?

A. Commonly the result of this accident is to tear off, or break, the front cylinder head, but the head should be removed whether injured or not, and the piston extracted from the cylinder; if the piston rod is not bent disconnect the radius rod and center the valve in the prescribed manner—except that of course the cylinder cocks will not need to be fixed open nor taken out on the disabled side—and move on.

Q. 64. In case of a bent piston rod what should be done?

A. Take down the main rod, disconnect the radius rod in the regular manner and center the valve securely. Use your own judgment as to blocking the cross-head—the piston and rod will usually be so cramped as to make blocking unnecessary.

Q. 65. In the too common case of blowing out a front cylinder head, what should you do.

A. Disconnect the radius rod and center the valve, both by the instructed method, except that in this case if the fixed-open cylinder cocks will not afford relief for the compression from the piston's back stroke it is only necessary to remove one—the back—cylinder cock; or better still, where there is one, unscrew the indicator plug from the back end of the cylinder. In this case of running with the main rod up one of the objectionable fea-

tures in doing so is removed—the general lack of facilities for oiling the piston in the cylinder—for with the front head off oil can easily be introduced.

When the back cylinder head is broken, it is best to proceed as directed in the case of bent piston rod.

GUIDE AND RODS AND THEIR TROUBLES.

Question 1. What is the use of the crosshead?

Answer.—It is a medium of connection between the piston rod and the main rod, by means of which the pressure exerted on the piston head by the steam is transmitted to the crank pin of the main driving wheels.

Q. 2. Why can not the main rod be connected directly to the piston rod?

A.—The strain on the piston rod, stuffing box and packing gland would be too great for obvious reasons, and to overcome this the crosshead working in guide bars is employed.

Q. 3. Describe the crosshead at piston end.

A. It has a horizontal tapering socket at this end, through which a tapering key-way is cut at right angles perpendicularly to the socket. This socket receives the tapering end of the piston rod, and a key is driven in the key-way which draws and holds the piston rod firmly in the crosshead.

Q. 4. What is the result if this key becomes loosened or broken, or the piston rod breaks?

A. If key becomes loosened it will result in a bad pound. If piston rod or key become broken the front cylinder head will be destroyed, and it will be necessary to disconnect the valve stem and cover ports.

Q. 5. How is the main rod end of the crosshead equipped?

A. With a wrist pin extending across the extended sides of the crosshead. The forward end of the main rod is connected to this wrist pin by a strap and bolts holding

brasses that fit around the wrist pin and are adjusted by means of a tapering key, which is held tight by means of a set screw through a keeper at the bottom of the strap.

Q. 6. If this key is not properly adjusted, what is the result?

A. A pound that may result in a broken rod strap and other consequent damage.

Q. 7. In case of a broken wrist pin, front end strap to main rod or crosshead, what is to be done?

A. Take down the main rod and such other parts as may be necessary from breakage by the accident, block crosshead back in guides, disconnect valve stem and cover ports.

Q. 8. Why should crosshead be blocked in back of guide bars?

A. Because front cylinder head is more easily and cheaply replaced in case of damage from crosshead getting loose in guides through blocking working loose.

Q. 9. Where will the wrist pin become the smallest through wear?

A. At the front and back side, owing to the direct pull and push of the piston. For this reason keying the front end of a main rod on the eighth will give the best result, although care must be taken not to get the brasses too tight, as no brasses will cut out more quickly if improperly keyed.

Q. 10. How are the sides of crosshead equipped?

A. With wings or slides that work between the guides and bear the weight of the crosshead and a portion of that of the piston and main rods.

Q. 11. Why are crosshead wings equipped with gibs?

A. To receive the wear where the crosshead travels in the guides. They can be replaced more easily and cheaply than a new crosshead could be put on.

Q. 12. Why is a wrist pin made heavy?

A. To withstand the strain to which it is subjected, and which is especially heavy on curves where it is subjected to a twisting motion.

Q. 13. What causes this twisting motion on curves?

A. The lateral play, or, more plainly speaking, the side motion between the hubs of the driving wheels and the inside of the driving boxes. This side motion will not amount to a great deal in a new engine, but will be considerable in one about ready for general repairs.

Q. 14. Driving boxes will slip back and forth on the journals where there is straight track; why is the twisting motion any greater on a curve?

A. Owing to the cramped condition of the rods, boxes and wheels on one side and their drawn condition on the other. The wheels on the outside of curve travel the farthest, so it is evident those on the inside must slip to keep them in unison.

Q. 15. How are guide bars put up?

A. Parallel with the axis of the cylinder.

Q. 16. Is there more than one type of guide bars?

A. Yes, the single bar, which passes through the crosshead and has piston and main rods attached to under side; the two-bar type, with one bar under and one above the crosshead; and the four-bar type, two bars above and two below the crosshead.

Q. 17. What are guide blocks?

A. Blocks which are attached at one end of the guides to the back cylinder head, and at the other end of the guides to the guide yoke by studs. The guides are bolted to these blocks. These blocks are subjected to great vertical strain.

Q. 18. What is done to reduce guide wear to a minimum?

A. They are made as hard and smooth as possible. The crosshead gibs are made softer than the guide bars to take the wear, as they can be renewed more cheaply and quickly.

Q. 19. How is the wear of the gibs compensated for to avoid lost motion before gibs are worn out?

A. By liners placed between the end of the guide bars and guide blocks, which are removed as the gibs wear and the guides closed. When new gibs are put in liners can be replaced.

Q. 20. Is the wear equal on all guide bars?

A. No; it is more uniform on yard or suburban passenger engines because they run more evenly in both directions, while the majority of locomotives do the greater part of the work running ahead. With them the upper guide bars receive the most wear, because when the stroke is toward the crank pin and the main rod is below the crosshead the pressure on the piston head makes compression on the crosshead and pushes it up against the guide bars, and on the return stroke the main rod is in tension and is above the crosshead, and pulls it up against the guide bars. Running backward the main rod, being in tension, pulls the crosshead down on the guide bars, and on the return stroke the main rod being in compression above the guide bars pushes the crosshead down on the lower guide bars.

Q. 21. At what point is the greatest strain exerted on the guide bars?

A. At their centers, as this point is farthest from the point of support, and also at that point the angularity of the main rod is the greatest.

Q. 22. Explain the difference in the motion of the different ends of the main rod?

A. The main rod and crank pin receive the pressure exerted against the piston by the steam and convey it to the wheel. This pressure gives to the front end of the main rod a reciprocating motion that corresponds to the motion of the crosshead. The back end of the main rod has a rotary motion that corresponds to that of the crank pin, and parts of the rod intermediate to these points have a combination motion of the two, varying from a reciprocating to a rotary, according to their distance from the crosshead or the crank pin.

Q. 23. Is there any loss of power owing to the varying angle at which the main rod transmits power to the crank pin?

A. None, except that which is lost through friction.

Q. 24. In what portion of the crank pin circle is the greatest power exerted on the pin?

A. When pin is on the quarter and piston is at the center of its stroke.

Q. 25. What are the dead points of an engine?

A. When the centers of the wrist pin, main rod, crank pin and main driving axle are in a straight line on one side, then the engine on that side is practically powerless and must be carried by these points by momentum previously gained, or by the engine on the opposite side, which is then working at its maximum power.

Q. 26. What is done in case of a broken main rod?

A. Take off the broken parts. Block crosshead, disconnect valve stem and cover ports.

Q. 27. Define compression and tension of a main rod.

A. Compression is when rod is pushed toward crank pin, and tension when pulled from the crank pin.

Q. 28. What are main rods?

A. Flat bars of wrought iron, larger at the crank pin

than at the wrist end. Some of them are fluted, as are side rods, to make them lighter and stronger.

Q. 29. Why are main rods made larger at the crank pin end than at the wrist pin end?

A. Because of the greater size of the crank pin. It has also been found that more main rods break at the crank pin end.

Q. 30. How are rod brasses made?

A. They are made in pairs, cored out to fit the pin, and dressed slightly less than a half circle to allow for keying when brasses become worn. They are held in place by U-shaped straps that surround the grooved sides of brasses, and slipping over the end of the main rod are held in place by bolts.

Q. 31. Is there any other form of brass used?

A. Yes, what is known as a solid brass. It is a round bushing of brass forced in the hole at the enlarged end of the rods. The objection to this brass is that when worn it can not be tightened to the pin by keying, and so is often worn loose to save putting in new bushings.

Q. 32. Do driving rod keys alter the length of the main rod?

A. With one key ahead of crank pin and the other ahead of wrist pin the length of the rod will not be visibly altered.

Q. 33. If the edges of the rod brasses meet and the key is tight, and the brasses are still too loose on the pin, what must be done?

A. The brasses must be reduced.

Q. 34. When should rod brasses be keyed where grease cups are used to lubricate pins?

A. After the locomotive has been run some distance, and after cups have been screwed down so that the grease

between the pin and the brasses will be worn out, otherwise the brasses will appear tight on the pin when in reality they are loose.

Q. 35. Why is babbit put in grooves in inner side of rod brasses?

A. Because they run cooler, and as babbit will fuse at a lower degree of heat than brass a warning will be given by its melting that would save more serious damage.

Q. 36. Why is it necessary to keep rod brasses keyed up properly?

A. To avoid their pounding. A pounding brass will heat the same as one keyed too tight.

Q. 37. Where should the back end of a main rod be keyed?

A. On the center, which should be the largest part of the crank pin.

Q. 38. What are the rods called that unite the driving wheels?

A. Side rods, connecting rods and parallel rods.

Q. 39. Explain these different terms.

A. Side rods are so called because they are placed on the sides of the driving wheels. Connecting rods, because they connect the driving wheels; and parallel rods, because the one on one side is parallel to the one on the other side and also to the rail.

Q. 40. Where should side rod brasses be keyed?

A. With engine on center on side that is being keyed, to avoid changing the length of the rod.

Q. 41. Should wedges be properly adjusted before side rods are keyed?

A. Slack wedges will cause more wear on recently keyed rods than would occur in natural wear many times over.

Q. 42. Should a rod key be slackened if a pin runs hot?

A. No, not unless it has been recently keyed and is found to be keyed too tight. Look for the trouble from some other source.

Q. 43. How should a middle connection be first keyed on a ten-wheel engine?

A. Drive both keys out and then drive one down, mark it when clear down with a knife, scratch even with top of strap and drive it out. Drive the other one down and mark it in like manner and drive it out. Start both keys and drive them down, and when brass is tight enough to suit, have mark on both keys equally distant from rod strap.

Q. 44. How can it be determined if there is a pound in rod brasses or a driving box?

A. Put engine on quarter on side to be tried and have fireman give cylinders a little steam and throw lever back and forth, "chug" her, it is termed. A pound will readily be found by this means. Do not key brasses so they will not yield a bit under "chugging" or there will be a hot pin.

Q. 45. What is to be done in case of a broken side rod or crank pin?

A. Take down side rods on both sides on an eight-wheel engine, and if a main pin the main rod on that side must come down.

Q. 46. Why must opposite side rod come down?

A. With nothing to guide it when it reaches the center it is as apt to go up as down, in the wrong direction instead of the right one, and then there will be more damage. On consolidated engines, when rod in front or back section breaks take down the same rod on the op-

posite side, as they have the same relation to each other as the side rods of an eight-wheel engine. If in middle section, all side rods must come down. On six-wheel connected engines, if back side rod breaks take down back side rods; if a front side rod breaks all side rods must come down, because knuckle joint back of pin would turn with crank pin and without rest of side rod.

Q. 47. Why are knuckle joints used on side rods on engines with more than two pairs of driving wheels, instead of a one-piece rod?

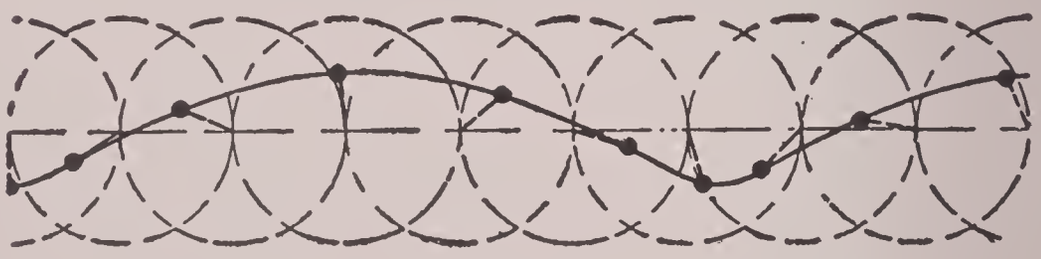
A. To allow the wheels to adjust themselves to the inequalities of the track.

Q. 48. Where should knuckle pins be located?

A. As near the crank pin as possible to lessen the strain on it. When one breaks it is to be dealt with the same as a broken back side rod.

Q. 49. Why are side rods made heavier in the center?

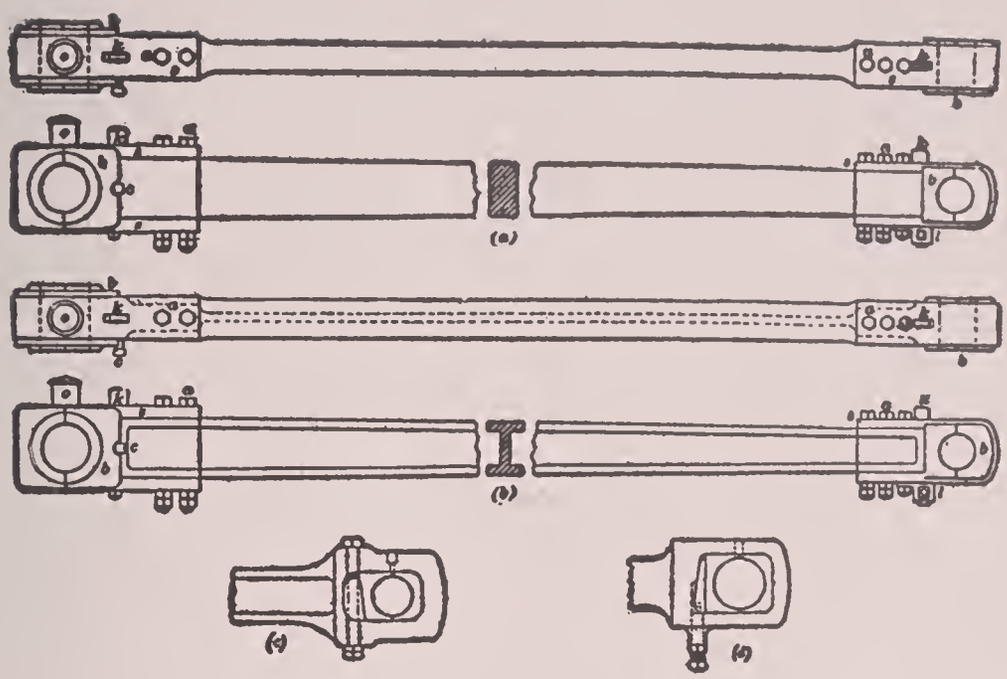
A. To make them stiffer in the vertical plane.



50. Motion of Main Pin.—"Please describe the motion of the main pin on a locomotive as it moves along?"

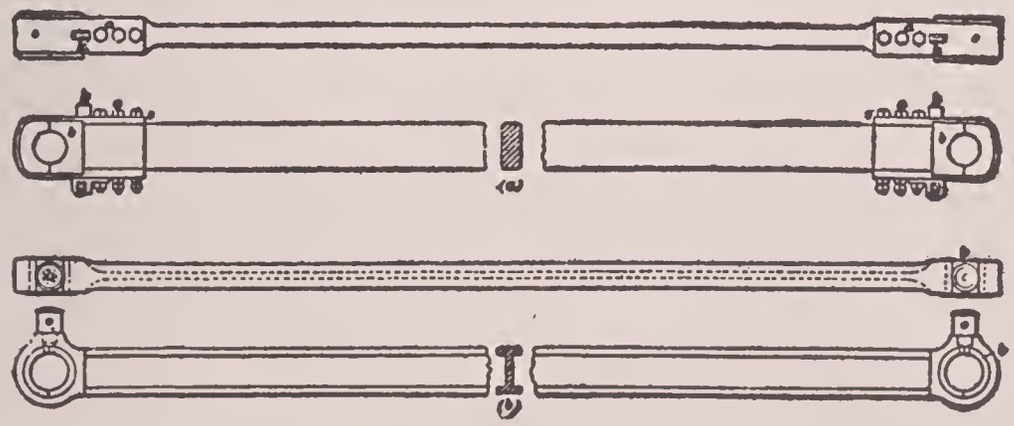
Answer.—The motion is like this: (See illustration.)

51. Handling Heavy Main Rods in Breakdowns.—"It puzzles me how I could handle a main rod on our largest locomotives in case it was necessary to take one down on the road. In some breakdowns, such as broken guides or crossheads, how would it be to let it down



TYPES OF MAIN RODS.

(a)-Rectangular cross-section type; (b)-I-cross-section type; bb, Brasses; ss, Straps; kk, Keys for adjusting brasses; cc, Set screws—and ll, Guards—securing keys in position; oo, Oil-cups.



TYPES OF SIDE RODS.

(a)-Rectangular cross-section type, with strap ends; (d)-I-cross-section type, with solid ends; kk, Keys for taking up wear of brasses in strap-end type; no provision made for this in solid-end type, but worn brasses must be replaced by new ones.

on the ground then pick it up and put it on the pilot. It would be so heavy that a man could not lift it."

Answer.—Get the train crew to help you handle the rod; call on the section men if you need them. There is always a way to bring in the broken parts, and they are necessary sometimes in order to get the engine in service. You would tie up the engine if you brought her in without the main rod; you can always get help.

52. Angularity of Main Rod.—"I placed the main pin on the top quarter with naked eye and made a mark on the guide bar, then I gave the wheel a half revolution and placed the pin on the bottom quarter and marked the guide bar, and I find that it varies almost 2 inches. I have tried this on 18 or 20 engines and have never found one that would come true. Will you please explain this?"

Answer.—Your eye is not accurate enough to measure this correctly and your system is wrong. Engine on the quarter means at half stroke. If you will place the cross-head at half-stroke and mark the guides, then move the engine until the cross-head travels to the end of the stroke and back to the mark again, you will get the engine on the top and bottom quarter, but the pin will be slightly in advance of a perpendicular line through the axle in proportion to the length of the main rod. That is, a short main rod will bring it farther from the line than a long one. Try it this way next time, or use a tram equal to the length of the main rod, and you can not miss it. This is caused by the angularity of the main rod, and also explains the reason that the circumference of the wheel travels farther on the rail from half stroke back to center and to half stroke again, than from half stroke ahead to center and back to half stroke.

53. Keying.—How should you commence to key up Mogul or Ten-wheel engine?

Answer.—The object in keying up the rods of a Mogul or ten-wheel engine is to secure a good accurate fit to the rod brasses without causing them to grasp the pins too tightly. The engine should be in steam and should be placed on straight level track. The wedges should be adjusted, all the keys should be slackened and the butt end of the main rod should be keyed first. The main crank pin should be upon the forward or back centre when this operation is performed. The other bearings should be keyed up on each side of the main pin. The engine should then be moved to the quarters and the other centre. It may be that the rods, while working freely at the dead centres, may tighten a little as they approach the upper or lower quarters. This is caused by the fact that the wheels are resisting the pulling force of the rods and it should be distinguished from tightening of the bearing at these points. If the connecting rods move freely on the bearings at both dead centres it is safe to assume that the bearings will run easily at all points, the only exception being in the case of crank pins that are worn out of all semblance to roundness.

54. Keying Rods.—"In posting for a mechanical examination one of our firemen had in his possession a clipping from a railway publication, which stated that a rod should never be keyed up on the center, even with a pin perfectly round, because, unless the valve has no lead, there will be a pressure one way or the other on the pin and the engineer is pretty sure to either key too much or too little, according to whether the pressure is with or against the key. Too much means a hot bearing and too little a pound; this, of course, on the supposition that the rod is keyed up when the engine is hot. With the pin

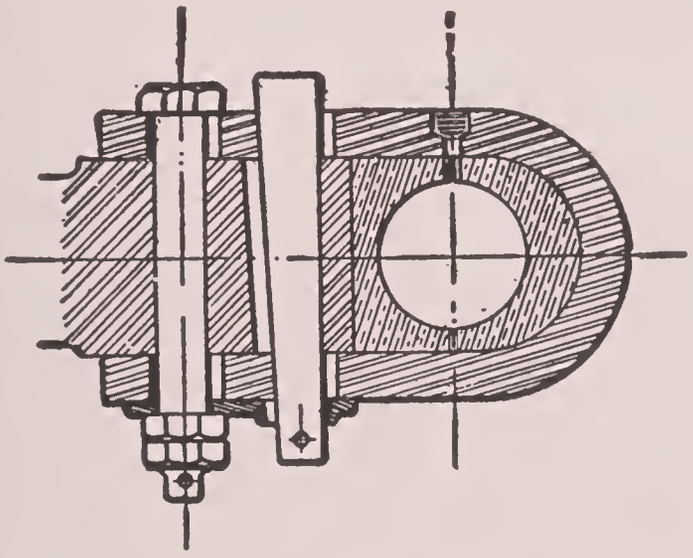
on the quarter and ports covered, the conditions are always the same, even for a new pin and for a worn pin, there is no question as to the quarter being the proper position. I failed to agree with the brother and we decided to refer the question to you for a reply."

Answer.—Would say in reply to the above that the throttle should be ground in, but, if it was desired to key up the rod, the engine should be placed on the center on that side to key all brasses except the front end of the main rod. Relieve the pressure in the cylinder, by opening cylinder cocks or placing a packing hook or iron under the air valve, raising it from its seat to allow the pressure to escape, then drive the keys to bring brass to brass, if the rod can be shaken on the pin; if not, drive the key up until you can shake the rod and the pin will run cool if the brass is filed square and it is properly lubricated. The least wear on the pin is when the engine is on the center, therefore, its largest diameter; and, if the brass will not pinch the pin at its largest diameter it will not pound or run hot when the brass is pushing or pulling on the small diameter.

The correct answer to the question is: To key the rod on the largest diameter of the pin, but care should be taken to observe that tightening the set screws on the key does not pull the key down. If the brasses are filed open, see that the brass is loose on the pin before you get up in the cab.

55. Keying Up a Draw Strap.—"They say you have to loosen the strap bolts before you key up a draw strap. Please explain how I may know if it is the draw strap by looking at it, and if it is correct to loosen the bolt. Do they use drawstraps on the back end of the main rod, or just on the front end?"

Answer.—A draw strap is used on the forward end of main rods on some classes of engines, and the key goes through the main rod and strap instead of being placed between the end of the rod and the brass. The bolt is a good slip fit in the rod, but the bolt-hole in the strap is slotted and you have to loosen the bolt before you can drive the key. With this arrangement in keying the front end of the rod it is shortened instead of lengthened. Observe the construction in sketch. Men have reported front end rod brasses filed when this kind of strap is used, because they were not familiar with it and did not loosen the bolt before trying to drive the key.



Draw-Strap for forward end of Main Rod.

56. KEYING SIDE RODS ON SIX-WHEEL CONNECTED ENGINE.—"Why should the side rods of a six-wheel connected engine be keyed up from the main connection first?"

Answer.—To insure free movement of the brasses on the pins and the main connection being keyed properly. If the front and back ends of side rods were keyed up first and the main connection last, there would be more liability of putting strain on either front or back

section of rods. Should you attempt to key the main connection up, brass to brass, and to have brasses free on pins, you would have to go over them again. Solid end rods are displacing straps and keys on modern engines.

57. KEYING SIDERODS ON SIX-WHEEL CONNECTED ENGINE.—"Keying up siderods on a six-wheel connected engine and two keys for front and back pin, would you drive both keys for each pin or just one, and if so which one would you drive?"

Answer.—Before keying siderods see that the wedges are properly set up. Then place the engine on a straight track on dead center on the side to be keyed. Key main pin or middle connection brass first. If necessary to slack off all other keys in the siderods, do so. When you get the main pin or middle connection brasses keyed, then key the back end brasses first, then the front end brasses last. Use both keys to get rods the proper length, then try rods on the other dead center. If you can move the rods easily on both centers you will have them the right length and properly keyed. Tighten up set-screws and you will have no further trouble.

58. TAKING OFF OPPOSITE SIDE RODS IN DISCONNECTING.—"Why do you have to remove the opposite side rods to disconnect, and what harm does it do the boxes if you do not take the opposite rods off?"

Answer.—If an engine is using steam in both cylinders and one side rod is bent, broken or for any cause is removed, the opposite rod on the other side should come down for the reason that with both main rods, by using steam on both sides, when one side is on the center the other side is on the quarter. Now imagine a ten-wheel engine with the back section of side rod removed on the right side and engine standing on the quarter on the

right side. The left side is on the center and all rods in a straight line with the center of the axle. When the throttle is opened steam is admitted to the cylinders. The right side being on the quarter, it will exert the greatest rotative force on that side and turn the wheels in the direction of the motion. The back wheel on the left side having the side rod up, and pulling on a straight line, may be undecided which way to go, whether in the direction of the others or in the opposite direction. The rod on the left side is liable to be bent or broken, or the pin broken or pulled out from the wheel center. This is the reason for taking down the opposite side rod when working steam on both sides of the engine. In case a main pin should break, or any other failure should occur which would require all side rods and main rod on that side to be taken down, you can safely leave up all side rods on the working side of the engine without causing further damage, for the reason that the power is applied to that side of the engine only, and the pin must be either above or below the center to enable the engine to move, and they will all be sure to move in one direction. No harm will result to the driving boxes and the wheels will trail all right on the dead side. This may be a little deviation from general practice, but it will work and save taking down all the side rods, and gives you three wheels instead of one to bring engine to shop.

59. Disconnecting a Consolidated Engine.—"An engineer running a consolidated engine with eccentrics not on the same axle as the wheels with the main pin, broke the main pin on the left side. He disconnected the valve stem on that side and took down all the side rods on both sides and succeeded in taking the engine 20 miles to the terminal. When the hostler took the en-

gine to put her in the house she was further damaged. In your opinion did the engineer disconnect her properly, and should the engineer or hostler be held responsible for the consequent damage?"

Answer.—It is our opinion that the engine was not properly disconnected by the engineer. By taking down all the side rods it left the wheels and axle that controlled the valve gear for the admission and exhaust of steam to the cylinders independent of the position of the piston or the main wheels. The reason for taking down side rods on opposite sides is that if one side was on the quarter the other side would be on the center, and the wheel connected by one side rod only would be liable to break the pin or start to revolve in the opposite direction. But in this case, where the engine was only working steam on one side, if all the side rods on that side were left up, should she stop on the center she would have to be pinched or moved until all the pins were above or below the axle a sufficient distance to insure their revolving in the right direction. Therefore, there would be no danger from leaving the rods up on that side to come in. It looks to us that the engineer was not only in big luck to reach the terminal under the above conditions but put the company to additional expense and set a trap that caught the hostler.

60. Wear of Guide Bars.—"When an engine is running forward and working steam, what part of the guides, top or bottom, does the cross-head bear against, and why does the bottom guide wear so much faster than the top one on all road engines?"

Answer.—When the engine is running forward the top guide will wear more than the bottom guide, because when the piston is at the forward end of the cylinder

steam is admitted, and as the pin passes the center the steam is pushing the piston back, exerting a pressure on the forward end of the main rod. The back end of the main rod being below the center the cross-head is forced upward or against the bottom of the top guide.

When the piston leaves the back end of the cylinder the steam in the cylinder is pulling the rod forward and on an angle after the pin leaves the center. The pull on the pin lifts the cross-head and causes it to wear on the bottom of the top guide. It is always pushing and pulling on the rod, and as the back end of the rod follows the crank pin circle it is always on an angle except when passing the centers, thus holding the cross-head up while working steam running forward, and pushing it down when running backward. If your engine is wearing most on the bottom guides when running ahead it is due to improper lubrication of bottom guides and cross-head, or else the guides are not in line. Road engines running ahead do not wear the bottom guides most.

61. Blocking Cross-Head.—"At which end of the guides would you block cross-head, and why?"

Answer.—Back end, as less damage would result in case it got loose. The front head would be the only one knocked out, and is less expensive to replace.

62. Engine Pounding When Shut Off.—"If an engine pounded when shut off and did not when working steam, what would you do to avoid damage to the engine, and what would you report?"

Answer.—Work a little steam to form a cushion and prevent pounding until stopped. Then examine travel of cross-head on guides and see if the length of the main rod had been changed in the shop. If it had, would change liners in rod brasses to lengthen or shorten as the

case required. Main rods get longer as the keys are driven. If we found the main rod to be of the right length would take off cylinder head and possibly find broken follower bolt or loose spider. If not, look for a sprung piston rod, and if piston rod was sprung would take down on that side to prevent damage to the cylinder.

63. Pound from Loose Pedestal Brace.—"A book by McBain states that a loose pedestal brace will pound on one center only, but gives no explanation. We created the cause and watched for effects, and believe the pound is in the back center. Will you say if this is right and the reason that the pound is only on one center?"

Answer.—An engine with a loose pedestal bolt will pound most when passing the forward center. When the engine is running ahead and the main pin is passing the back center, the pound due to the driving box taking up the lost motion is minimized to almost nothing, on account of the jaw or shoe that the box is to come in contact with moving away from it, or in the same direction as the box when it takes up the lost motion; and the pound or blow that the box strikes the shoe and which is transmitted to jaw and frame is not as intense as when the pin is passing the forward center. With the driving box moving in the opposite direction from the wedge, the difference in the pound on front and back centers is similar to the difference between a head-end collision with two trains running in opposite directions and a rear-end collision with two trains running in the same direction at different speeds, or just as it is easier to row a boat with the current than against it.

64. What is The Defect.—"Please explain what defect, if any, and about what percentage of power is lost in the following: Long piston, cylinder is 18x24,

135 pounds of steam, and 55-inch driving wheel. Piston just clears the front end 1-64 of an inch, clearance on other engines of the same make is 5/8 of an inch divided. This engine does not give satisfaction and the trouble cannot be located anywhere except a long piston. If this affects the lead or pulling power, please advise."

Answer.—If this engine is still in service the clearance should be attended to at once, as it is not sufficient to allow for the keying of the main rod to take up the wear on the brasses, and there is danger of knocking out the front cylinder head. We will presume that this engine originally had 5-16 of an inch clearance at each end of the cylinder and the clearance on the front end was reduced on account increasing the length of the main rod by driving the keys. That being the case, we have 1-64 of an inch clearance on the front and 39-64 of an inch on the back end. Neglecting the space between the circumference of the cylinder and the valve face, we would have a volume of clearance in the front end of about 4 cubic inches and a clearance volume in the back end of about 130 cubic inches. The position of the eccentric in relation to the pin is not changed, therefore, the lead of the valve would be the same, and if cutting off the steam at 5 inches of the stroke, or when the piston had moved 5 inches from the end of its travel, we would have a volume of steam in the front end of the cylinder equal to 1,276.5 cubic inches to force the piston back by its expansive force. In the back end of the cylinder we would have a volume of steam equal to 1,402.5 cubic inches to push the piston ahead, which would give a higher mean effective pressure in the back end than in the front end of the cylinder. This increased volume of steam confined in the cylinder when the valve is closed

the admission port may cause the exhaust from the back ends of the cylinders to sound heavy. Would have the clearance divided for each end of the cylinder and take up the dome cover and see if the throttle valve opened enough to admit steam to the dry pipe in sufficient quantity to develop the required power in the cylinders. The throttle valve should lift ¼ of an inch for each inch of its diameter to get the full opening.

65. Leaving Back Port Open in Case of Breakdowns.—"Would it be advisable or practicable, in case of broken eccentric strap, link rocker-box or arm, to leave the back port open a little to admit steam and oil to cylinder, instead of taking down main rod?"

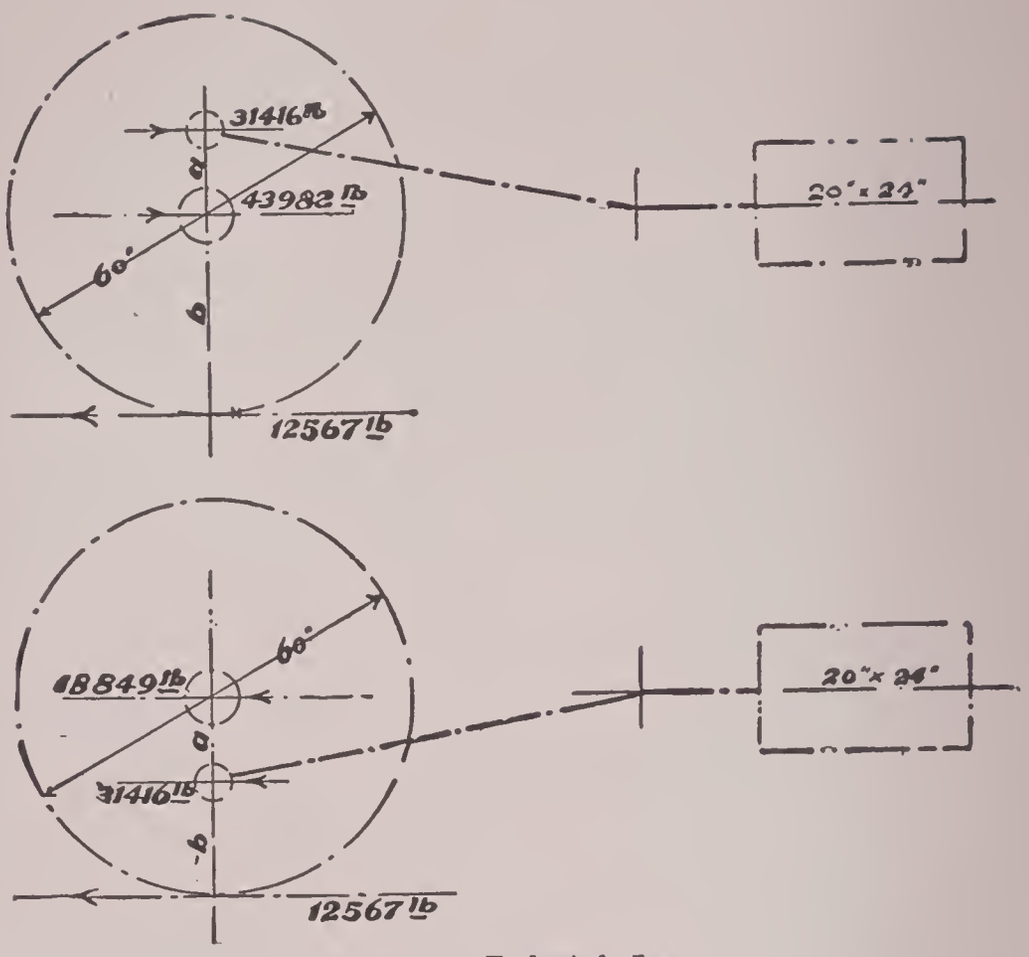
Answer.—Yes, unless prohibited by the rules of the mechanical department. By clamping the valve in position to allow steam to enter the back port, steam and oil will be admitted to the cylinder and it will not be necessary to take down main rod. The amount of opening of the port that should be left open may be determined by opening the throttle and blocking the cylinder cock open, or remove the valve from the cylinder cock. Some roads advocate taking the cylinder cock out entirely and blocking the valve in position to allow a reasonable amount of steam to escape at all times when the throttle is open. Then, in case the engine should stop on a center, on the good side, closing the cylinder cock or replacing valve or cock sufficient steam will be admitted to the cylinder to complete the stroke on the disabled side, which will place the good side again on the quarter; the valve or cock can again be removed on the broken-down side and you are in position to start the engine when ready to go. With heavy power it is impossible for train crews to pinch engines off a center or handle the rod if they succeeded in

getting the strap bolts out, which is often a difficult thing to do. This is practiced on some of the important lines at the present time and is considered the correct method.

66. STRESS ON PEDESTAL JAWS.—"Is the stress on the pedestal jaws the same when the crank pin is on either quarter, the engine running ahead under steam? I think it is greater when the crank pin is on top quarter. Am I right?"

Answer.—Yes. Suppose you had an engine with a wheel 60 inches in diameter and a cylinder 20 inches in diameter, stroke 24 inches. This would place the center of the crank pin 12 inches from the center of the axle. The area of a 20-inch piston is 314.16 square inches, and if we had 100 pounds of steam pressure in the cylinder, when the pin was on the top quarter we would have a pull of 31,416 pounds on the crank pin. Now, looking at the wheel as we would look at a lever, we have the point in contact with the rail at the fulcrum. The main axle is the load or weight to be moved and the pin is the power. This gives us a lever of the second class, in which $a=12$ inches and $b=30$ inches; power applied at $p=P\times\frac{(b+a)}{b}=W$, or the stress put on the pedestal when in this position, which is 43,982 pounds.

With the pin on the bottom quarter we have a lever of the third class; $a'=12$ inches and $b'=18$ inches; we have $\frac{P\times b'}{a'+b'}=W$, or the stress on the pedestal when crank pin is on the bottom quarter, which is 18,849 pounds when in this position. Please note illustration.



Stress on Pedestal Jaws.

67. Crosshead Gib on Top of Single Bar Guide.—"Please explain why the gib in the crosshead on top of the single bar guide of a mogul engine is left loose, or what effect it would have if made tight in crosshead?"

Answer.—The gib in the crosshead can be made to fit tight, provided that it will permit a free movement on the guide bar. When they are not tight it is usually due to wear. With this type of crosshead it is difficult to keep them tight, and they wear rapidly, on account of the horizontal and vertical motion of the crosshead.

68. Length of Main Rod.—"What is the correct way to determine the length of a main rod?"

Answer.—If guides and cross-head are up and main driving box set properly in jaw, place the cross-head in

exact center of guides and use a square, measuring from center of main driving box. When adjusting a main rod to the proper length you should always notice whether the key in the back end is in front of or behind the crank pin. When in front, you lengthen the rod as the brass wears and the key is driven down, and when behind the crank pin the rod is shortened. Divide your clearance accordingly and always consider the space occupied by the piston rod in the back end of the cylinder, which should have 1-32-inch more clearance than the front end to equalize the exhaust. Therefore to get the correct length of a main rod, place the cross-head 1-32-inch ahead of center of travel and measure to center of the axle and you have it.

69. MOVEMENT OF CROSS-HEAD.—"Will you please explain if it is true that a cross-head moves only one way or direction; I have heard that it does, but do not believe it?"

Answer.—In order to make you believe it we will take a driver with a diameter of 42 inches and a piston with a 2-foot stroke; will use this because it will come out in even figures. To prove to you that the cross-head is always moving in the direction that the engine is going, multiply 42 inches by 3.1416; this will give the circumference of the wheel equal to 131.9472 inches. We will call this 132 inches, which, divided by 12 inches, equals 11 feet; remember that the stroke is 2 feet and the circumference of the wheel is 11 feet. With the cross-head at back center, if you measure 5 feet and 6 inches from the point of contact of the wheel and rail and move the wheel that distance, the engine has moved 5 feet and 6 inches, the cross-head has moved with the engine 5 feet and 6 inches, and in addition has moved in the guides 2

feet, which gives 7 feet and 6 inches that the cross-head has moved while the pin has traveled from back to front center. If the wheel is now moved ahead 5 feet and 6 inches farther, the pin and cross-head will be again on the back center, but the cross-head has lost the 2 feet that it gained in the forward stroke and has only traveled a distance of 3 feet 6 inches, but the 7 feet and 6 inches it traveled on the forward stroke and the 3 feet and 6 inches on the back stroke will equal 11 feet, or the circumference of the wheel. It's going ahead all the time.

SPRINGS AND EQUALIZERS.

Question 1. With what is a locomotive provided to minimize the bad effect of the weight of so heavy an object moving at high rate of speed on the track and roadbed?

Answer. Springs and equalizers (which carry much of the weight of the locomotive in a swing, as it might be termed) that yield to the inequalities of the track.

Q. 2. Would the jar also have an injurious effect on the locomotive if it was not supplied with springs and equalizers?

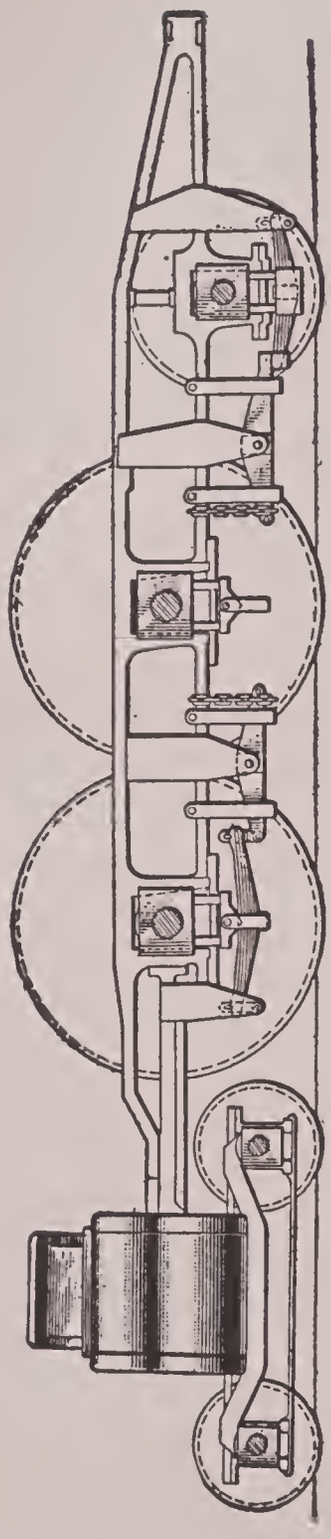
A. Yes. Every engineman knows that over rough track an engine will shake itself loose, and it is easy to determine how much greater the jar would be on the parts if not safeguarded against. A stuck wedge will give one a good idea of what a locomotive would be like if unequipped with springs and equalizers,

Q. 3. What consideration is had in designing and specifying the axle of a locomotive?

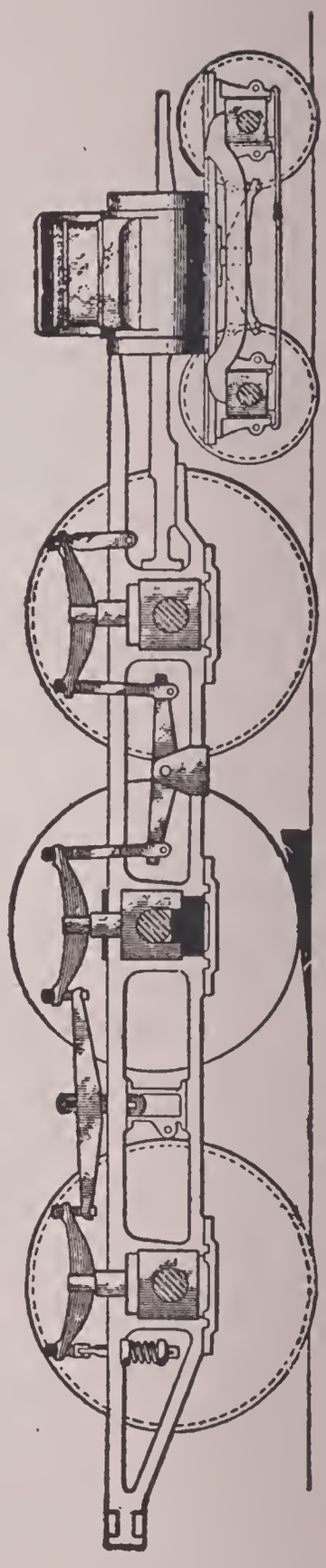
A. The load that the axle will be expected to bear, and the weight per yard of the rail on which the locomotive will run when placed in service.

Q. 4. What is the important point in selecting a spring for any given locomotive?

A. It must not be made so stiff as to make the locomotive ride rigid, and at the same time it must be strong enough to bear its load without breaking except under unusual strain, and stiff enough not to straighten out and lose its set, as that destroys the value of the spring and



Showing what to do in case of Broken Main Driving Spring on an Underhung Engine.



Method of Raising and Blocking Wheel for Broken Tire.

allows the engine to become low at that point and the frame to strike on the driving box.

Q. 5. How is the extra weight thrown on any particular spring by uneven track distributed among the other springs?

A. By the equalizers connecting the springs. For example: If the back wheel on either side was going over a high spot on the roadbed that driving box would be raised by the wheel and journal, pushing it up against the spring saddle at the center of the spring, thereby increasing the load on this spring, and it would yield a certain amount to the extra force thus applied and would transmit the rest of the extra load to its equalizer. The equalizer would in turn bear a portion of it and deliver the rest to the next spring, and so on throughout the connecting springs and equalizers on that side of the locomotive until the extra load was entirely distributed or equalized.

Q. 6. With overhung springs, on what do the centers of the springs over the driving boxes rest?

A. On a V-shaped saddle that straddles the top rail of the frame, with the points of the V resting on the top of the driving box and the center of the spring resting on top of the inverted V.

Q. 7. What holds the back end of the rear spring to the frame and its front end to the equalizer?

A. Irons called hangers. By means of them the frame and boiler is swung from the boxes. This arrangement of hangers is continuous for all the springs on one side of the engine, a spring being provided for each driving box.

Q. 8. If only springs were used and no equalizers in connection with them, what effect would be produced on rough track?

A. There would be an increase in friction on the journal to that box owing to the extra load placed upon it, and therefore a greater tendency for the box to become hot. Heavier journals and springs would also be required.

Q. 9. Are any locomotives built without equalizers?

A. Yes. Some four-wheeled switch engines of a light build, but they break many springs, as yard tracks are not always kept in the best condition.

Q. 10. How are underhung springs and equalizers arranged?

A. Differently than the overhung spring, although their duty is the same. In one style four bolts pass from top to bottom through the driving box near its outer edge, one at each corner, and sustain a pocket in which the center of the spring rests. This pocket is equivalent to the saddle with the overhung spring.

Q. 11. Where are springs and equalizers placed on engine with underhung springs?

A. Below bottom rail of frame.

Q. 12. Describe other types of underhung springs.

A. One kind with a hook at top of the hanger, that catches over the top of the driving box; four of these to the box support a pocket for the center of the spring. Another style puts the center of the spring curve up under the top rail of the frame with the centers of the springs blocked beneath it and the ends connected to equalizer bars that rest edgewise on top of the driving boxes and extend beyond them.

Q. 13. What is the fulcrum of an equalizer?

A. The part that is attached to the frame by the equalizer stand.

Q. 14. Is any provision made to catch underhung springs in case of a broken spring hanger?

A. Most locomotives are equipped with safety hangers.

Q. 15. In case of a broken spring or spring hanger on an engine equipped with overhung springs, what is to be done?

A. Run wheel with broken spring on a wedge, pry up end of equalizer that is down and block it, and run wheel off from wedge. Run wheel next it, or, if a ten-wheel engine and it is the middle spring, run the ones on each side of it on wedges and block between top of driving box and frame over box where spring is broken. Run wheels off wedges. Remove any loose parts that might do more damage or get lost. Oak wedges should be iron bound to keep them from crushing under the weight of heavy engines. Blocking between tops of driving boxes and frame on boxes with good springs will aid in getting engine up high, but these blocks must be taken out after the other work is finished.

Q. 16. Does a broken spring or hanger sometimes bind the reverse lever reach rod so that the lever cannot be moved?

A. Yes. This happens often in case of breakage of right back spring, more particularly on 8-wheel engines, and occasionally with the front spring.

Q. 17. If a spring or hanger breaks and binds the reach rod as that engine cannot be run up on blocks on account of lever being hooked up, how can this difficulty be overcome?

A. Remove the pin connecting the reach rod to the lifting arm of the tumbling shaft. This will allow the links to drop down in full gear, and engine can be run ahead as desired and reach rod and lifting arm again be connected when necessary.

Q. 18. How should one proceed for a broken equalizer, equalizer stand or stand bolts?

A. Run wheels on that side on each side of disabled equalizer on wedges and block on top of driving boxes and under top frame. Remove equalizer, springs and spring hangers. Run engine off wedges and everything is ready for service.

Q. 19. Where should a block be placed to carry the weight with underhung springs in case of a broken equalizer, spring or spring hanger?

A. Between top of driving box and frame the same as with overhung springs.

Q. 20. How can one determine where to block on engines with underhung springs?

A. Determine the direction in which the force is exerted on that spring or equalizer and block against the direction of this force. In other words, block to place the spring or hanger on equalizer in the position it was before the breakage.

Q. 21. Is there anything that will aid one in determining the true position of an equalizer or spring when a breakage occurs?

A. Yes. Note the position of the same parts on the opposite side of the engine. This will give the right position of the part.

Q. 22. How would one block an equalizer with a broken spring or spring hanger?

A. Run wheel or wheels with good springs on wedges and pry equalizer in position and block it. Run wheels with good springs off wedges and wheel with broken spring on a wedge and block on top of its driving box. Remove such broken parts as may be necessary, run wheel off from wedge and the work is complete.

Q. 23. How can the load be lightened on a journal with a broken driving box brass or with a journal cutting?

A. With an engine equipped with overhung springs block between spring saddle and frame; this will put the weight in a measure on the other journals on that side. With underhung springs block equalizer so as to put the weight on the other journals. By determining the direction of the force on the equalizer this can easily be done. Plenty of oil on this box will also be a great help in stopping its cutting.

Q. 24. What is the best material for blocking for driving boxes?

A. Oak wood. It will bear much weight without crushing and is not so unyielding as iron. With some forms of driving boxes one has to use whatever can be worked in on the box, such as a flue plug or a big nut. Conditions often have to govern a good deal.

Q. 25. How is the weight of the forward part of a locomotive carried?

A. On an engine truck. This truck is equipped with springs and equalizers.

Q. 26. How are the equalizers placed on the 4-wheel type of engine truck?

A. The ends of the bars rest on the tops of the truck boxes and extend from one box to the other on that side, one at each side of the box.

Q. 27. How are the springs hung?

A. A spring with the curve up is placed between each pair of equalizers. The ends of the springs are held by hangers and the curved part extends above the equalizers.

Q. 28. What rests on the top of the springs?

A. Bearings on the side of the center casting. This casting is attached to the truck frame.

Q. 29. How can one block for a broken engine truck spring or engine truck spring hanger?

A. Raise engine truck frame up and block between it and top of equalizer. If one has no jack a short stick set slanting under the truck frame, with the other end on a tie and moving the engine toward it, will do the work of a jack screw.

Q. 30. How can one block for a broken engine truck equalizer?

A. Raise engine truck up and block between engine truck and tops of truck boxes.

Q. 31. How could one block for a broken intermediate equalizer on a mogul engine?

A. Block on both front driving boxes, under boiler and over cross equalizer.

Q. 32. What is done for a broken tank spring?

A. Raise tank up at that corner and block between truck and bottom of tank. As a rule a broken tank spring can be run in without harm.

Q. 33. In case no jacks are available, how can a tank be raised up to block it for a broken spring?

A. By means of a stick set under the corner of the tank that is to be raised and extending away from the tank, with the other end resting on a tie. Move the tank toward the stick until the corner is raised to the desired height for blocking. As most engines are no longer equipped with jack screws, something of this kind must be adopted to raise tanks or engine truck frames.

Q. 34. If an equalizer is found to be cutting the fire-box, what is the trouble?

A. Engine is low on that side, equalizer is bent or equalizer stand is bent. Raise engine up on that side or straighten equalizer or stand; this will remedy the defect.

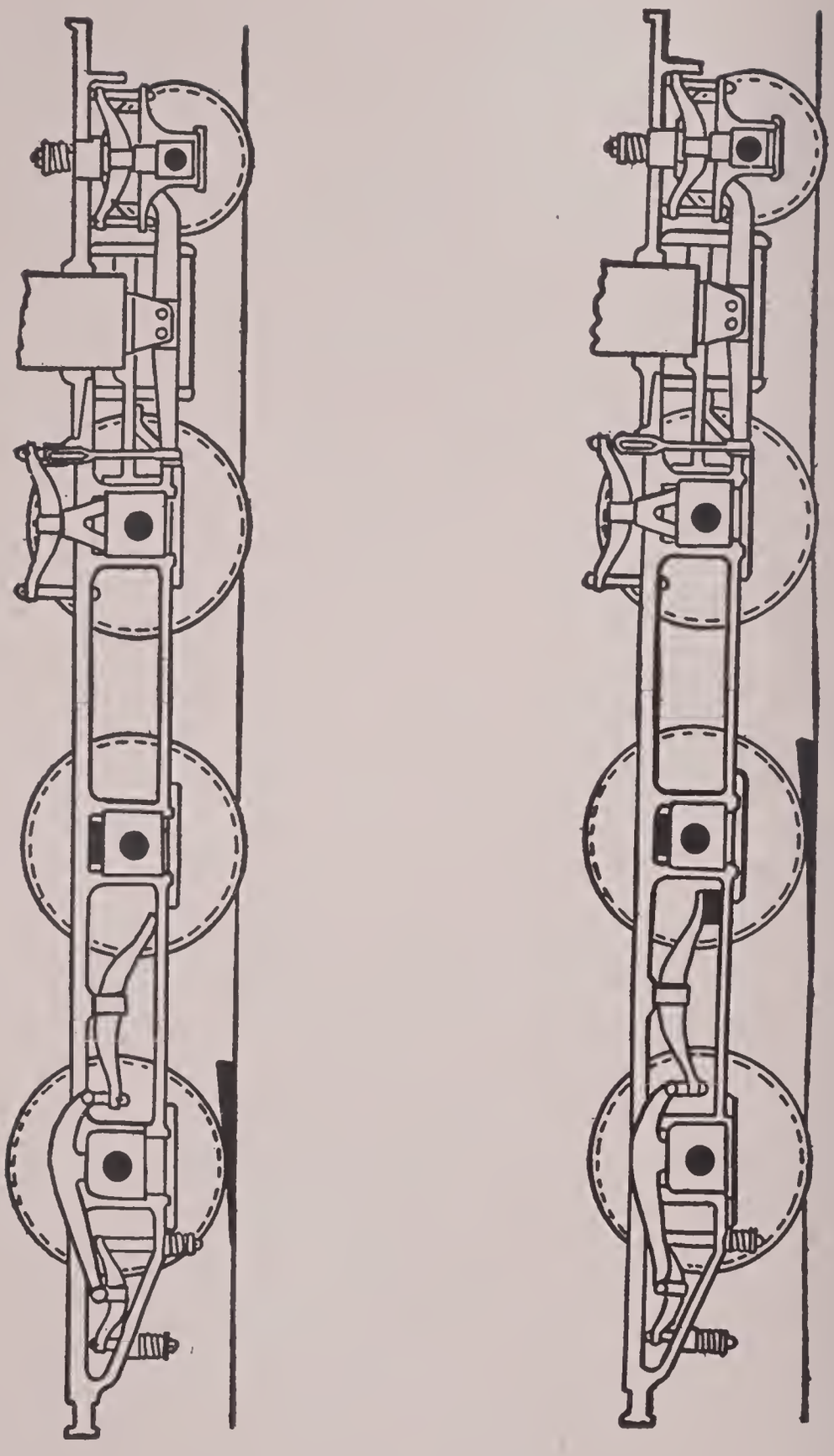
Springs that have lost their set will cause an engine to get low; in this case new springs would be all that would be needed.

35. BROKEN DRIVER OR TRAILER SPRING, HANGER OR EQUALIZER.—"How would you proceed to block up for a broken driver spring, spring hanger or equalizer on a class D engine; how for a broken trailer spring or hanger? The class D is a Northwestern type."

Answer.—For a broken front driving spring, run front driver up on a wedge, then pry up the front end of the equalizer nearest to the broken spring until it is in about normal position and place a block either between the front end of the equalizer and the lower bar of the frame, or between the back end of the equalizer and the top rail of frame. This gives the use of the main driver and trailer springs. Now run the front driver off the wedge and the back driver up on the wedge, and block between the top of the front driving box and the frame so the front driver will carry its load, remove or secure broken parts.

If equalizer broke between the front and back drivers, raise up engine with jacks or in any other manner, and block between lower hanger pins and the bottom of the top rail of the frame.

When a trailer spring breaks it allows the end of the cross equalizer nearest the end of the broken spring to drop into the safety hanger. First jack up the end of the cross equalizer into position and place a block in the U-shaped safety hanger to hold it until you are ready to remove it. Now raise the back end of the engine frame so she will ride level, remove the broken spring and take a tie or a piece of rail and place it over the trailer box and chain front end of the cross equalizer, and the back



Method of Blocking for Broken Spring, Spring Hanger, or Equalizer. First raise frame by running wheel up on wedge, and block as indicated by upper figure. Next raise second driver on wedge as indicated by lower figure, which will release tension so that block can be placed under spring as indicated.

end to the frame and hanger pin, remove the block from the safety hanger under the cross equalizer and let the usual load come on the trailer box.

If a front hanger on a trailer spring should break, raise the back end of the engine on the disabled side so as to relieve the trailer spring, then jack up the end of the cross equalizer next to the broken hanger, pry down the front end of the trailer spring and securely chain the end of the spring to the end of the cross equalizer.

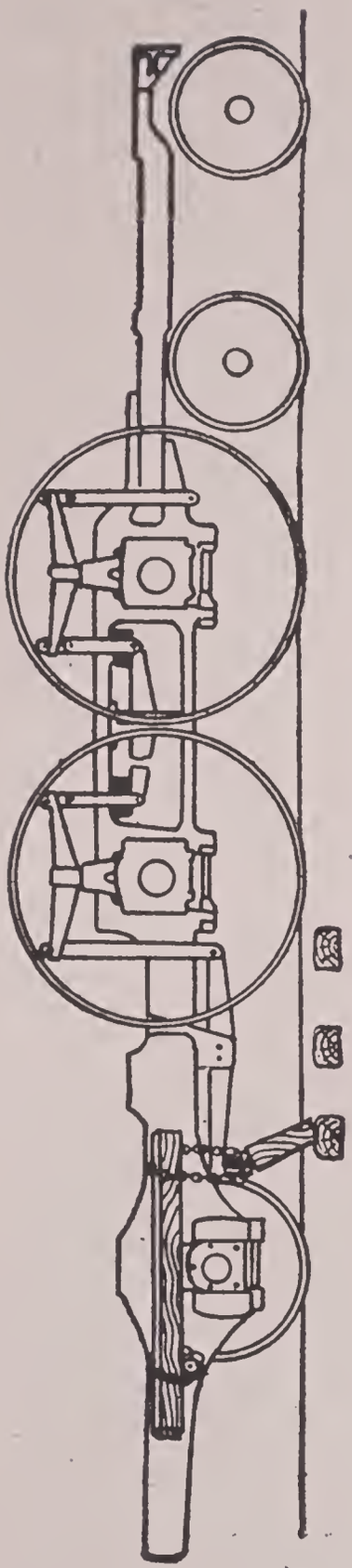
If a back hanger on trailer spring is broken, raise the back end of the engine and also jack up the end of the cross equalizer to relieve the spring, then pry the back end of the spring down and chain it so it will not work off the hanger pin.

36. Broken Engine Truck Equalizer on Consolidated Engine.—"If you broke the long equalizer of engine truck on a consolidated engine what would you do?"

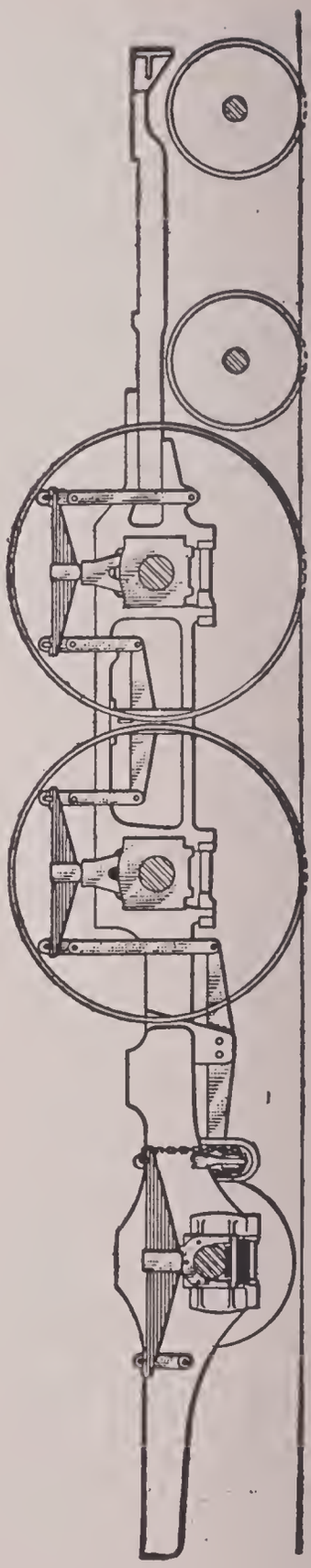
Answer.—Remove loose or broken pieces and block between driving box and frame, both sides, so as to carry the frame rigidly on the front boxes.

37. Underhung Springs and a Broken Tire.—"How should a standard eight-wheeler American engine with underhung springs be handled in case of a broken tire? Spring saddle extends into the bottom of the driving box and is held in position by a pin?"

Answer.—This is a poor design of a driving box for a case of this kind, as the cellar is raised in the center to clear the steel pin that supports the spring saddle, this pin extending through the box is held in place by the face of the shoe and wedge. When the tire breaks, if it still remains on the wheel, it is necessary to keep it from the rail, and if it is broken so that it comes off the wheel, the



Method of Raising Cross-Equalizer.



How to Handle a Broken Trailer Tire or Broken Trailer Equalizer.

wheel center must be raised to keep it from being damaged. We will take for example the forward tire broken. We will insert a block between the top of the back box and under the top rail of the frame, take out the cellar and see if we have space enough between the spring saddle and the journal to put in a block that will hold the broken tire from the rail. If not, it will be necessary to remove the pedestal or thimble bolt. Then run the back driver up on a wedge to raise the lower end of the pedestal jaws or legs of the frame above the pin. Take out the pin, remove the spring and saddle, and cut a block from the end of a timber or tie that will fill the space between the pedestal bolt and the journal when the wheel will clear the rail. Have it thick enough to allow for wear and settling. Chain the end of the equalizer to the frame and run the back wheel off the wedge. Then put the pedestal bolt back in place and tighten the nuts. Now put the wedge under the wheel with the broken tire and run the wheel on it until you can insert the block between the pedestal bolt and the journal. Run the wheel off the wedge and you are ready to proceed. If the back spring is heavy enough to carry the load the blocks may be removed from the top of the back box and the back spring utilized.

JOURNALS, TIRES AND FRAMES.

Question 1. What causes driving journals to break?

Answer. Crystallization of the metal or its natural weakness, or being subjected to great and unusual strain.

Q. 2. Is the strain greater on a driving journal with a large or with a small wheel?

A. Greater on the journal with the large wheel.

Q. 3. Why?

A. For the reason that it requires more power to propel a given object the greater distance. For instance, if a driving wheel covered 20 feet of ground at each revolution it would require more power to move a given load that distance in a specified time than it would to move the same load the same distance in the same period of time with a driving wheel covering 15 feet at each revolution.

Q. 4. Suppose that the forward driving journal on a six-wheel connected locomotive should break outside of driving box at hub of wheel, what must be done?

A. Take off all side rods and remove wheel out of the way. Raise axle up at broken end parallel with the other driving journals and block it there with a block placed between driving binder and journal, leaving wheel at the other end of the journal on the rail. Ask for help if needed, as often other serious damage is done where breakages of wheels, tires or journals are involved.

Q. 5. How can one block for a broken journal on an 8-wheeled engine?

A. If it is the main journal remove side rods and main

rod on side where wheel is broken off, and remove wheel out of the way. Raise journal up and block it in position with a block between driving binder and journal. This applies where broken off outside of driving box. If journal is broken between driving boxes ask for help, as it will be quite a job to get engine ready for towing. If a back journal outside of driving box, take off side rods and put disabled wheel out of the way. Raise the broken end of journal up and block as before. It will be necessary to chain this corner of the frame up to a piece of rail laid across the tank deck and chained down at the opposite end. Block between tank and on side where wheel is to keep it on track around curves. If broken between the driving boxes, remove side rods and chain rear of engine up to tank, blocking journals up as before described.

Q. 6. What is to be done for a broken back journal on a 6-wheel connected engine?

A. If broken outside of the driving box, remove the disabled wheel and back side rods. Raise journal up in position and block between journal and driving binder, leaving wheel at the other end of the journal on the rail. Block between tank and engine on side where wheel is to keep it on rail around curves. Run slow. If broken between driving boxes, remove back side rods and back wheels, or raise them up and block them to clear rails.

Q. 7. What is to be done in case of the breakage of a main journal on a 6-wheel connected locomotive?

A. If outside of driving box, take off all side rods and main rod on disabled side. Remove disabled wheel out of the way. Raise and block broken end of journal in position, leaving wheel at the other end of the journal on the rail. If main axle is broken, get engine ready to be towed, and in either case send for help, as with main journal disabled help will always be required.

Q. 8. Should the cellar be taken out in the case of a broken driving journal?

A. If the journal is broken outside of the driving box, yes. If inside of the driving box, no.

Q. 9. What should be done in case of a broken front tire on a 6-wheel connected engine?

A. Run the wheel with the broken tire on a wedge, and raise it high enough to allow for settling and clear the rail, and block it up between binder and journal, removing cellar. The side rods need not come down unless damaged. A tire may only break so that engine may be run in slowly without anything being done, or a piece may come out of it, or it may go all in pieces, so that individual circumstances must largely govern the method of procedure.

Q. 10. What is to be done in case of a broken main tire?

A. Raise broken wheel up to clear rail and block it there. If side rods are uninjured leave them up, but slacken side rod keys to allow free motion in case any cramping has taken place from raising journal up. Run slow.

Q. 11. What should be done in the case of a broken back tire on a 6-wheel connected engine?

A. Block up as before given. Wedge on side where good tire is, between tank and engine, to keep wheel on rail around curves.

Q. 12. What is to be done in case of a broken driving wheel?

A. Proceed as for a broken tire on the same, only side rods must come down.

Q. 13. Why are some driving wheels made without flanges on their tires?

A. To allow for a larger driving wheel base, that will curve safely, than could be had if all driving wheels were flanged. Usually the tires on the forward pair of driving wheels and the two middle pairs on consolidation engines are left unflanged. They are commonly referred to as blind drivers.

Q. 14. What is to be done in case of a broken flange on an engine truck or driving wheel?

A. If only a small break, run slow. If a bad break, proceed as for a broken tire or wheel.

Q. 15. If a wheel or a journal breaks on front engine truck, how should one proceed?

A. Chain engine truck frame and truck box at broken wheel or journal to main frame after raising front of engine and truck up, then put a timber between main frame and engine truck frame and let front of engine down.

Q. 16. How should one proceed for a broken back engine truck wheel or journal?

A. Raise back end of truck up and chain engine truck to main frame.

Q. 17. What should be done in case of a broken tank wheel or journal?

A. Fasten a timber across top of tank and chain broken corner of truck up to it.

Q. 18. What causes flanges to cut?

A. Engine too low on side that is cutting.

Q. 19. Is there any other cause for flanges on driving wheels cutting?

A. Yes. If wheels are not parallel with each other, or square as regards the cylinders, the wheel too far back will cut its flange.

Q. 20. Is there anything else that will cause engine truck wheels to cut their flanges?

A. Yes. If engine is not in center of engine truck the flanges will cut, and engine should be moved toward side that is cutting to relieve it.

Q. 21. In case of the breaking apart of the tank and engine, what must be done?

A. That depends greatly on the other damage resultant from the breaking in two. If only tank or engine pin is broken a substitute can generally be found. If drawbar between tank and engine is broken, chain tank and engine together and run a switch rope or heavy chain from engine pin to head car. If this breaks the other chain will hold tank and engine together, and there will be no danger of injury to the fireman. Sometimes water hose will be so damaged that it will not be possible to get water into boiler, in which case the fire must be put out and engine made ready to be towed. Generally by using the good parts on both sides, one injector can be put in shape to be serviceable.

Q. 22. Of what material are locomotive frames made?

A. Wrought iron.

Q. 23. How are they constructed?

A. Double throughout, except in the 8-wheel type of engine. In that class, from in front of the union of the upper and lower sections an iron bar 4x4 inches extends to the pilot beam. This part in conjunction with the top bar of the double frame is commonly called the main frame.

Q. 24. What forces does the frame of a locomotive receive?

A. The pull and push of the pistons and the resistance of the train which is exerted upon it.

Q. 25. What is that portion of the frame called that encloses the driving boxes?

A. Pedestal jaws. They extend down from the upper rail of the frame, two for each driving box. These jaws project far enough below the driving boxes to allow for the attachment of the pedestal binders, extending from one jaw to the other, and which really form a part of the frame. The pedestal jaws are usually braced from the succeeding jaw, or by a diagonal brace to the top rail of the frame.

Q. 26. How are the pedestal binders held in place?

A. One kind is made flat with tapered notches to fit over the pedestal jaws, and having holes for bolts and studs by which it is drawn up tight. Another kind is square with a large hole through it lengthwise. It fits between the jaws of the pedestal, and by means ot a large bolt passing through them and the binder it is drawn tight.

Q. 27. When a driving binder gets loose, what does it cause?

A. A bad pound in that box. If left alone and it gets very loose, a broken pedestal jaw or main frame may be the result.

Q. 28. Is one style of binder to be preferred over the other?

A. No. Not if both are fitted properly, although, as a rule, the binder that is held in place with one large bolt can be kept tight the more easily.

Q. 29. How is the diagonal brace extending from the main frame to the pedestal jaws fastened?

A. It is welded fast to jaw near bottom and to top rail of frame.

Q. 30. For what is the front end of the main frame used?

A. For the attachment of the pilot beam.

Q. 31. What is fastened to the main frame near its front end?

A. The cylinder saddle.

Q. 32. How is it fastened?

A. Bolted to the frame, and by off-sets in the frame slightly farther apart than the length of the cylinder saddle; a key is driven between the off-set and the saddle, making it fit tight on the frame.

Q. 33. If a cylinder saddle key becomes loose, what is the result?

A. The cylinder saddle commences to work on the frame and soon shears the saddle bolts off unless it is fixed.

Q. 34. How else are the cylinder saddles fastened?

A. To each other and to the smoke arch. Braces also extend from the smoke arch to the pilot beam.

Q. 35. How is the frame fastened to the boiler near its center?

A. By means of the guide yoke, which is fastened to the boiler shell at its middle, and near its ends to the frame. On very large engines another brace is sometimes attached to the boiler shell at its center, and to the frames at its ends.

Q. 36. How is the frame attached to the firebox?

A. The frame passes through slides that are fastened to the firebox. This allows the boiler to slip on the frame when undergoing expansion and contraction, which is greatest at the firebox end of the boiler.

Q. 37. What amount on an average does the boiler slip on the frame?

A. About ¼ of an inch.

Q. 38. Why are frames made in sections or parts on each side?

A. Frames are nearly always injured in a collision or derailment of any seriousness. With the frames in sections one of them can be removed, repaired and put back in position with much less labor and expense than if the frame was one continuous piece. The front section is easiest to remove on account of the driving boxes in the back sections.

Q. 39. In case of a broken frame or pedestal jaw, what should be done?

A. It depends on the nature and location of break. If between front driver and cylinder, and the crack opened up much when working steam, it would be best to give up train and go light, or else take down main rod on that side, and then more than likely train could not be handled. If break was between drivers, side rods could be taken down, and then engine would probably have to go light. If break was not too bad, would go along as usual with train, favoring engine when possible to do so. If pedestal jaw was broken go along as usual, only another engine should not pull on an engine with a broken frame.

40. Broken Back Tire on Eight-Wheel Engine. —"Will you please state how to block up an eight-wheel engine with broken back tire, without blocking over main box, as the road that I work on will not allow it to be done?"

Answer. Run the wheel with broken tire up on a wedge or block, then remove cellar and insert block between the axle and pedestal bolt or brace to hold the broken tire or wheel center off the rail. Also block between drawbar and tail piece, bolted to ends of the frames, so as to relieve the forward or main boxes of as much of the weight as possible. If the side rods are

not damaged by fire breaking, leave them up. When you have done this, if the spring over the main box is not strong enough to carry the weight or has lost its set, blocking may have to be used over main driving boxes or engine trucks to keep the pilot high enough to clear crossing planks. In case this should be the back tire on right side and raising the box would bring the spring and hanger so high that it would interfere with the reach rod or reversing lever, it would be necessary to remove the spring and saddle from the box with the broken tire and block the back end of equalizer on the frame.

41. Broken Front Tank Wheel or Axle.—"What should be done in case of broken front tank wheel or axle; if you swing them is there any danger of the second tire leaving the track, especially when the engine is running on curves?"

Answer. This, like all other breakdowns, should be governed by conditions, such as weight and construction of tank, capacities, etc. Engines with small capacity tanks may often be chained to a tie or piece of rail placed over the top of the tank, and blocking placed between the frame of the tender and the top of the truck boxes on the good pair of wheels, which would support the weight, while the chains would hold the other end of the truck up to prevent derailment. In some cases the apron may be removed and the pieces of rails or ties placed lengthwise of the tender, one end resting on the deck and the other on the bottom of the tank, and the broken end of the truck chained to them. With a six or seven thousand gallon tank it is usually better to get the engine to a side track and send for a truck; this can best be done by sliding the wheels or blocking them up and securing them to a notched tie, when the damaged truck

wheels or frame may be skidded into clear; run carefully in any case of this kind.

42. Broken Axle or Back Tire on Consolidated Engine.—"How would you block up for a broken axle or back tire on a consolidated engine?"

Answer. When the back driving axle breaks, if no other damage is done, remove both sections of side rods, jack the broken end of the journal up level and secure it by blocking between the bottom of the box and pedestal brace. If the firebox extends over the frame and the springs are between the pedestal jaws and under the top frame rail, pry up the back end of the spring as high as possible and block it there. Disconnect the front end of back equalizer if necessary to do so. If the springs and equalizers are above the frame, the block should be placed between the top of the frame and the spring saddle. The object in either case is to relieve the box of the weight it carries. If the second and third drivers have blind tires, chain around the tail piece of the engine frame on the disabled side and across to the opposite side to front corner of tender frame, using wedges to hold it as tight as possible, and this will crowd engine over against flanged driver. Cut out the driver brake, run carefully, especially around curves and through frogs and switches. With a broken tire, handle in the same manner, with the exception of taking down back sections of siderods, which may be left up if they are not damaged to warrant their removal.

43. Broken Tire on Consolidated Engine.—"If you broke a tire on same class engine how would you fix it up to bring engine in?"

Answer. If it was a front tire, would run broken wheel up on a wedge to bring it to about its normal posi-

tion, remove the oil cellar and fit a block in its place, using a piece of a tie, leaving it about flush with the bottom of the driving box, and then fill in the space between the bottom of the driving box and block and pedestal brace, with another block. Put some well oiled packing in space around the journal to lubricate it, then put an iron block between the top of the frame and the spring saddle so as to take the weight off the box; then cut out the driver brake. If a main tire, would block up in same manner, but if found that the spring would not carry the load would block ends of equalizers next to the broken wheel instead of blocking between the frame and the spring saddle.

44. Broken Tire.—"In case of a broken tire, where the tire can not be removed, should the wheel be raised to clear the rail, leaving the good wheel on the rail? Would the cramped position not be injurious to the engine?"

Answer. If on a ten-wheel engine and the front tire was broken, would run the broken tire up on a wedge to raise the wheel high enough to allow for settling, and still have the tire clear the rail when the cellar was removed, and a block of sufficient thickness put in its place to keep the tire from coming in contact with the rail when the wheel was run off the wedge, and if the rods were not sprung, would proceed with full train. If the main tire was broken would block up in the same manner and slack up on the siderod keys on that side, running carefully without train to the terminal. With a back tire broken would block up as in former cases, trying to throw as much weight as possible against the good wheel, and would use wedges between the tank and engine to assist in keeping the flange of the good tire

close up to the rail, running carefully, especially around curves. Having any one wheel high enough for the tire to clear the rail nicely will not cramp the boxes or be injurious to the engine. If the sides of the driving boxes were a close fit on the sides of the shoes and wedges, the driving-box would cramp when one wheel was raised higher than the other, and damage would result by breaking off the flanges of the driving box. To save the flanges of the driving-boxes from breaking on account of rough or uneven track, the inside of the flanges are beveled where the sides of the shoes and wedges fit, so that only about four inches of the sides of the shoes and wedges have a bearing in the center, and the bevel from the center to both ends on the side of the flange obviates damage from cramping the flanges of the driving-boxes when one wheel center is raised slightly higher on one side than on the other.

45. What should be done in case of breakage of the tender-wheel?

Answer. A tie or piece of rail should be placed across the apron of the tender to keep the wheel from turning, with blocking between it and the tender body; the broken truck should be chained to the tie at both ends of the latter, and the train should be run into the nearest telegraph station with that pair of wheels sliding—the broken part of the wheel being, of course, away from the rail.

46. Broken Back Driving Wheel.—"What should be done in case of a broken-back driver on an eight, ten, or twelve-wheel engine?"

Answer. Handle in the same way as with the broken tire, but take down the opposite side rods on each side of the engine.

47. Broken Tire or Axle on Four-Wheel Switch Engine.—"How would you block up for a broken tire or axle on a four-wheel switch engine?"

Answer. If back tire or axle, block it same as for back tire on consolidated, and block on top of driving box of good wheel on disabled side, chaining across to tender frame. If front tire or axle breaks, block up on top of back boxes, raise wheel or axle of broken tire and chain across to car to hold good flange against the rail. If necessary, a car or truck may be used to support front end of engine to get her to the shop.

48. Broken Aleck Bolt on Mogul Engine.—"What should be done in case an aleck bolt broke on a mogul?"

Answer. Block up between truck axle and front end of long equalizer, place a truck brass on the axle and allow the end of equalizer to rest on it. Oil the brass well, and you can get in without trouble.

49. Broken Pony Truck Center Pin or Long Equalizer.—"In case of a broken pony truck center pin or long equalizer on any engine with a two-wheel forward truck what would you do?"

Answer. Aleck bolt or long truck equalizer broken, raise the front end of the engine above its normal position. This will take the tension off the front driving box spring. Now jack up the front end of equalizer and place a block of hard wood or a truck brass on top of truck axle and allow the end of the equalizer to rest on it. If kept well oiled where the brass rides the axle, it will give no trouble. Should the equalizer break between the fulcrum and the end so you could not use brass on journal, jack up and place a tie or short piece of rail across top of frames in front of cylinders and chain

broken equalizer to it. This will hold the front end of equalizer solid and will give the use of the front driving spring. Run carefully with an engine blocked in this manner.

50. Lining Wedges.—"When it becomes necessary to line down a wedge, why is the liner put behind the wedge and nothing put behind the shoe? Should not both shoe and wedge be lined up and wheels trammed? Does the shoe not wear as fast as the wedge, and if not, why not?"

Answer. The reason for lining down a wedge is usually because it is pushed up so far that it strikes the frame and can not be set up any further to keep the box from pounding, and by making it thicker, placing a lining on the back of the wedge, it fills up the space between the box and jaw, and can again be adjusted to take up the wear. Wheels are trammed only for the purpose of keeping each pair of wheels square with the frame after the engine has left the shop. It is not necessary to tram all wheels when the wedge is lined up, if the engine is running true. If the liners were put in between the shoe and jaw it would be necessary to tram the wheels to insure a good job. As a rule, where the engine is running ahead, or doing the greatest amount of work in the forward motion, the shoe will wear faster than the wedge.

51. Blocking for Broken Engine Truck.—"In case of a broken engine truck, either forward or back, is it necessary to block on top of the front driving boxes?"

Answer. It may be necessary to block on top of front driving boxes and run the front drivers up on wedges to relieve the weight on the engine truck so that it can be easily raised and properly chained to an engine frame. If a mogul or an eight-wheel engine, it is usually neces-

sary to block on top of the front driving boxes, but six and eight-wheel coupled engines as a rule do not require it. It is up to the judgment of the engineer in all cases. Block on top of the front driving boxes if necessary to keep the pilot sufficiently high for safety in passing frogs and crossings.

52. AXLES AND VIBRATION.—"To settle a dispute will you please say why a car axle is made with a smaller diameter in center than at the ends near the wheels. Various reasons have been given; one is said to be to save iron; if so, why is not the same practice carried out in the driving and engine truck axles?"

Answer. The reason that the driving and engine truck axles are of the same diameter their entire length is due to the fact that the bearings carrying the load are inside of the wheels, and the uneven joints in the track, when passed over by the wheel, do not tend to vibrate the axle as they would when the weight is carried on the bearings outside of the wheels as in the case of a truck or trailer axle with outside bearings. When the weight is outside of the wheel, as it passes over uneven track the axle being of a smaller diameter in the center allows vibration to take place in proportion to the force of the blow imparted by the load to the uneven track and the size of the axle. If it was not for this vibration broken journals would be of more frequent occurrence, unless the track was perfect, which condition it would be impossible to obtain, as it would have to be laid with continuous rails without frogs or switches. Figure that the truck axle is smaller in diameter in the center for the same reason that the axe handle is not the same size its full length, and the illustration will be convincing to the person using the axe.

53. Broken Frames on Right Lead Engines.—"Please state reason for so many right locomotive frames breaking on right lead engines."

Answer. You do not state if the engines are equipped with double or single front rails on the engine frame. There may be many causes—poor design, welds, or material, or water in cylinders. Where the right side leads the engine always pounds harder on the right side than on the left, because when the right crank pin passes the forward center the left cylinder is pulling forward. This helps the right cylinder in pushing the right box back against the jaw of the pedestal, and the same results occur on the back center on the left side. This is usually the cause of more right frames breaking than left on right lead engines, and by having the left engine lead the trouble would only be transferred from one side to the other. One master mechanic reduced the number of broken frames by keeping the thimble bolts tight and wedges set up on the class of engines that were giving trouble.

54. Effect of Changing Driving Wheels.—"What would be the effect of changing the main pair of drivers end for end?"

Answer. On American locomotives the right-side engine leads the left-side engine one-quarter of a turn, or, in other words, the crank pins are set at an angle of 90 degrees to each other, and when the right side is on forward center the left side would be on the top quarter, eccentrics set at right angles to the pins and advanced toward the pins the amount of lap and lead. If you could take the main wheels, axle and eccentrics out and turn them end for end and give them one-quarter of a turn forward, the main pins and eccentrics would be in iden-

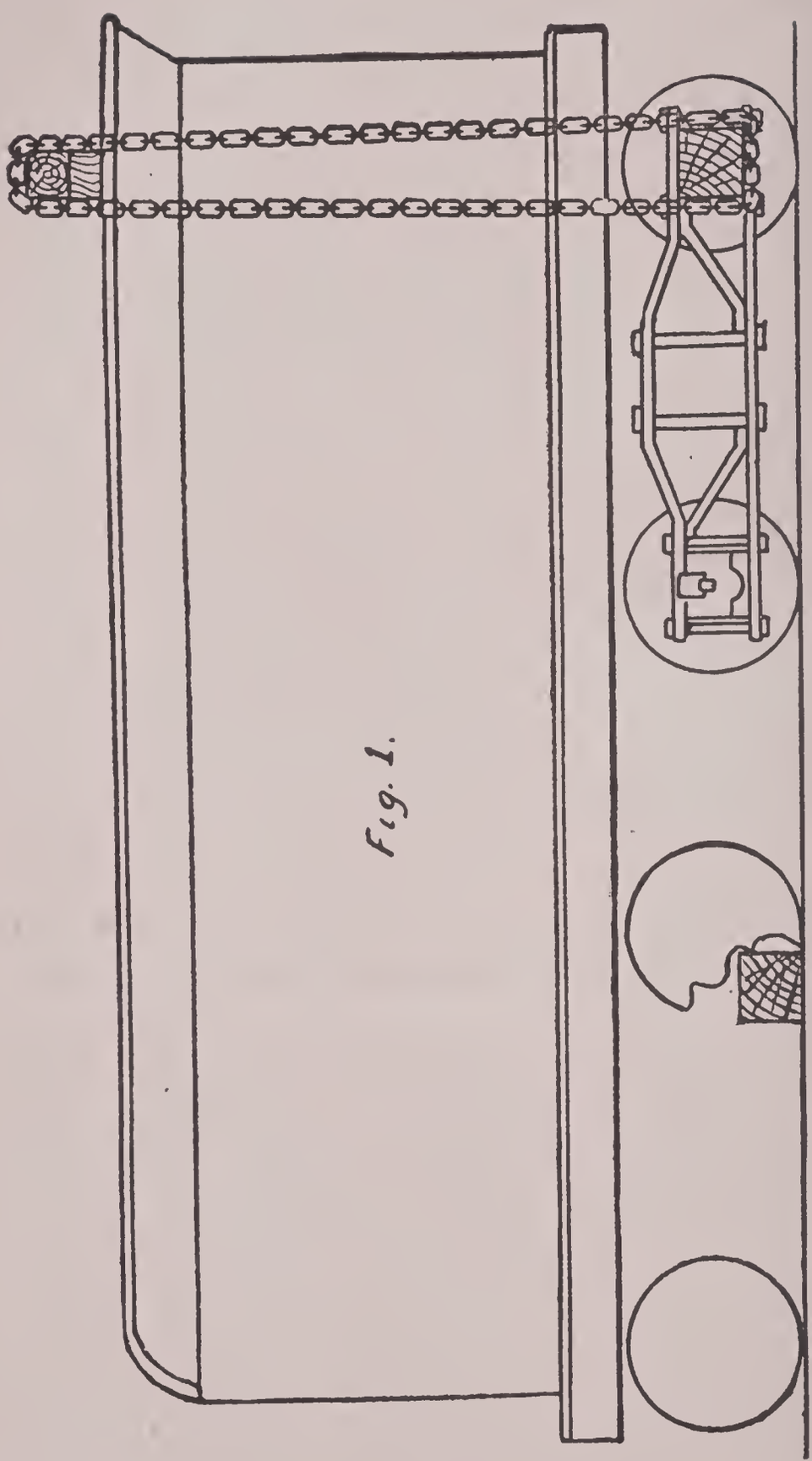
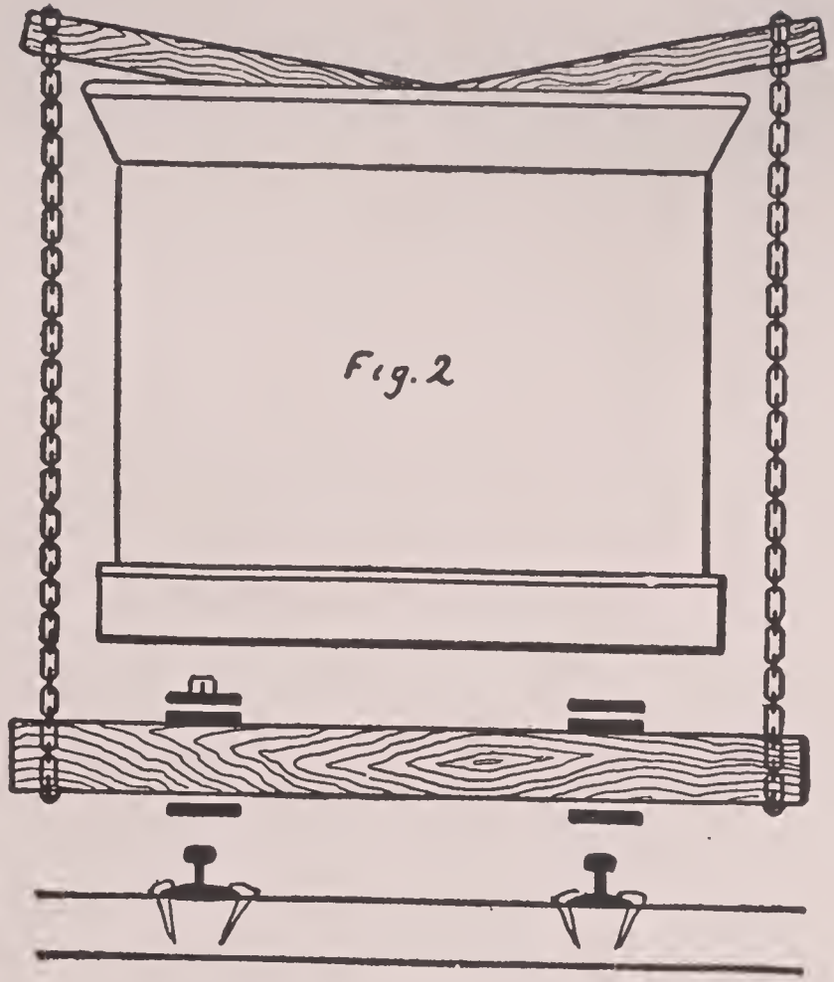
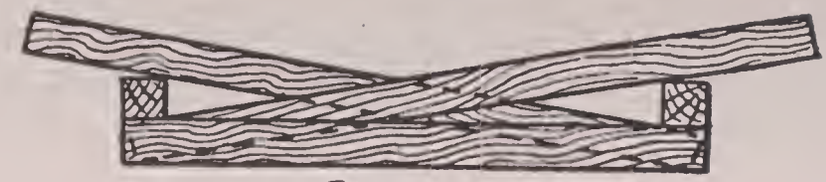


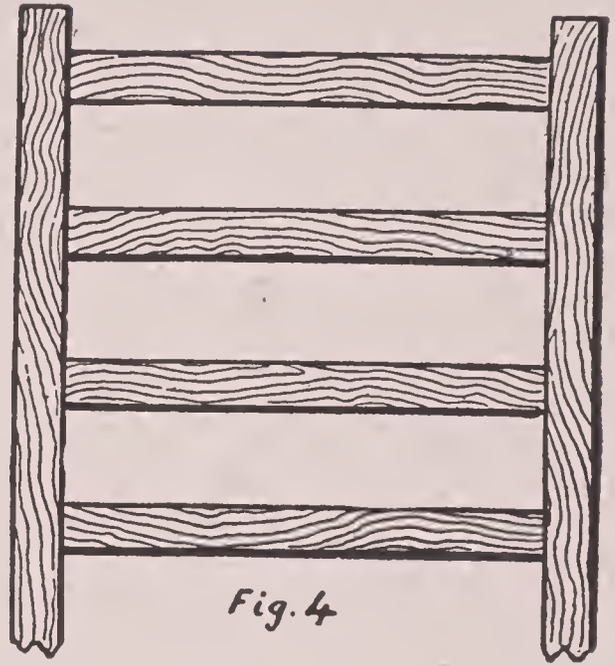
Fig. 1.

Showing (at front) Method of Sliding Broken Engine or Tender Truck Wheel to Side Track, by Placing Tie in Front of Defective Wheel.

Also showing (at rear) chain from ties on top of tank as arranged in Figs. 2, 3, and 4 on opposite page, to tie placed between arch bars, with oil-boxes removed for the purpose.







How to Bring a Tender in with Broken Truck Wheel.

Ties are laid over top of tank as in Fig 4; two locking and overhanging ties are placed as in Fig. 3; from these are hung chains as in Fig. 2, passing around tie placed between arch bars, with oil-boxes removed for the purpose. A side view of the arrangement is shown in Fig. 1 on opposite page.

tically the same position as before. Take a piece of cardboard about the size of a dollar and stick pins in it to represent the crank pins, mark the position of the eccentrics on the paper and then turn it end for end. The change will have no effect.

55. ENGINE OUT OF TRAM.—"What is meant by engine out of tram?"

Answer. When the distance between any two wheel centers on one side of the engine is not equal to the distance between the wheel centers of the corresponding wheels on the other side, or when the axles are not square with a line drawn through the center of the cylinders.

ROD PACKING AND DRIVING BOXES.

Question 1. What kind of packing was first used extensively for valve stems and piston rods?

Answer. A soft, fibrous packing of hemp or similar material saturated with some lubricant to insure better wear. It was of rope form, and packing piston rods and valve stems was a part of the engineer's duties, and seldom a stop was made that some of the packing did not require more or less attention, from screwing up the gland nuts to putting in a ring of packing, or perhaps renewing all in some stuffing box.

Q. 2. What advantage for a long time did soft packing have over metallic packing?

A. It was to a certain degree elastic, and adapted itself to any inequalities of the rod, and would not leak steam under conditions that hard packing would.

Q. 3. What were the objections to this kind of packing?

A. The expense of almost constant renewing, and that it would often need renewing when on the road and cause a consequent delay to an important train.

Q. 4. Did metallic or hard packing, as it is commonly termed, at first meet with general favor with shop and road men?

A. No. Its introduction was slow. The metal rings first used leaked steam badly and could not be kept tight as designed, and besides there is always a disposition in mechanical circles to regard any innovation with suspicion, especially where it involves the outlay of money to make the change.

Q. 5. What device was then adopted to hold the rings close to the rod?

A. A cone cup next to the gland in which the metal rings were placed and held there by a spring.

Q. 6. What effect had steam on this packing?

A. It increased the pressure on the packing rings and pressed them closer to the rods.

Q. 7. Did this improvement make the packing satisfactory?

A. No. It was found when the piston rod moved away from the center line of the stuffing box that the rings could not follow, and therefore they were mashed by the crowding of the piston rod and were rendered unfit for use, as the packing would leak until renewed, and new rings would suffer the same fate.

Q. 8. How was this difficulty overcome?

A. By the use of a ring called the adjusting ring.

Q. 9. What is the adjusting ring?

A. A flat ring with a ground joint where it fits against the inside of the gland. The hole in the ring is made somewhat larger than the rod. The cone cup fits against the inside of the ring and has a ground joint.

Q. 10. What is the purpose of this device?

A. To permit of the flat surface of the cone cup sliding on the ring laterally with the rod while, owing to the hole in the ring being larger than the diameter of the rod, the latter can move sideways without injury to the packing rings.

Q. 11. Did this device meet all requirements?

A. Not altogether. While it did fairly well for piston rod packing, except where the rod was more out of line at one end of the cylinder than the other, it proved to be far from satisfactory for valve stems.

Q. 12. What improvement was then made in the adjusting ring?

A. It was given a ball joint on the side next to the gland.

Q. 13. What did this allow?

A. The rod to go where it would laterally and the packing to follow without any steam blow, because there would always be a tight joint between the rings and the rod, the cup and the rings, and the ball joint of the adjusting ring and the gland.

Q. 14. Is the same style of gland in use with the metallic packing that was in vogue with the soft packing?

A. No. Not generally, at least. The gland used for soft packing fitted into the stuffing box, and the packing was tightened by forcing the gland deeper into the stuffing box. The style now in use for hard packing fits tight against the cylinder head and holds the packing tight in place.

Q. 15. State another difficulty in finding a satisfactory metallic packing?

A. The fixing of a proper angle for it. The angle must not be too acute nor yet too obtuse. The perfection of the ball joint for packing for valve stems aided greatly in securing a satisfactory packing.

Q. 16. Give another reason why it was hard to get a satisfactory valve stem packing.

A. Because an engine is run largely with a short cut-off, bringing the valve rod wear largely in one place and making it smaller at the point where the rod worked through into the steam chest.

Q. 17. How was this trouble overcome?

A. By using an extended gland that put the packing out on the stem beyond this shoulder. With the short

gland this shoulder on the stem worked through the packing and spread it, causing it to blow. A flange is used with the extended gland to surround the spring, which rests between the rings and the inner shoulder of the stuffing box.

Q. 18. How should piston and valve rods be made to aid packing in giving the best results?

A. They should be as true and smooth as possible. A rough rod or one out of round will speedily spoil a set of packing.

Q. 19. What care should be taken with cone cup and rings?

A. The cone cup should conform to the size of the rod, and the rings should be made to fit the rod, for if they do not they will not wear to a fit and will always leak or blow. The adjusting ring must allow for the play of rod laterally, but must fit rigidly to the gland to avoid steam leakage.

Q. 20. What is the duty of the packing spring?

A. To hold the packing rings firmly in the cone cup when the steam pressure is not against the rings.

Q. 21. What provision is made for keeping packing oiled?

A. A swab containing waste is fitted around the rod. This is saturated with oil by the engineer when oiling. An oil cup is used quite frequently in conjunction with the swab.

Q. 22. Is a swab that does not encircle the rod as good for lubricating the packing as one that does?

A. No. The rod will be lubricated all around better with a swab that encircles the rod. Plenty of oil in the valves and in the cylinders will be of great benefit in

lubricating the packing and keeping it in good shape. It is really the best method of lubricating packing.

Q. 23. Should packing be oiled before engine is moved out of roundhouse, more especially where engine has stood in the house for some little time?

A. Yes. The packing will be the better for it, as it will not be so apt to stick to the rod. Pouring some oil directly on the rod outside of the gland is a good practice. Leaky packing is both disagreeable and dangerous, and is quite a menace in frosty weather when the condensed steam obstructs the view of the engineer.

Q. 24. Why is oil that adheres to the rod from within the steam chest and cylinder the best method of lubricating packing?

A. For the reason that the oil on the swab may become exhausted on a long run or blown away on a short one if the packing leaks, but the oil from within is applied regularly and keeps the packing well oiled under all conditions if the valves and cylinders themselves are not starved for oil. Oil starvation is one of the greatest faults of the present day in locomotive running. Injury is done to the rod and cylinder packing, and to the valves and cylinders themselves, in addition to the extra strain put on other parts of the machinery. Add to this the increase of the coal consumption, and the cost per pint for valve oil saved will be rather high.

Q. 25. What else causes packing to give poor results?

A. Being put in by cheap and incompetent workmen who have about as much real knowledge of mechanical matters as they have of matters pertaining to the law.

Q. 26. What is the use of driving boxes?

A. To form a medium to receive the weight of the engine that is allotted to the drivers, and to receive the friction of the driving journals when running.

Q. 27. How should driving boxes be designed?

A. They should be heavy enough to bear the weight they are expected to carry under ordinary conditions without heating. They should be proportioned in weight and size to the load they are to bear and the friction heat they are to resist.

Q. 28. Has this always been done?

A. No. With the building of larger engines the desire to keep the weight, and consequent cost of the engine, down has often led to driving boxes being adopted that were too light for the work required of them and they would heat badly in actual service, and engineers were often blamed for not overcoming the faults of poor designing by unattainable ability in running. Small engines as a rule have heavier boxes proportionately and are not so liable to heat, and when they do it is generally attributable to some easily traceable cause or possible neglect.

Q. 29. What material is most favored by locomotive builders for driving boxes?

A. Cast steel.

Q. 30. Why is it preferred over cast iron?

A. Cast steel boxes can have the required strength and size and be made a great deal lighter than cast iron. Babbitt metal can be used on the bearings next to the shoes, wedges, and hubs, and this will give a surface of desired softness. Cast steel driving boxes will be lighter and tougher than cast iron ones, and will work to a better bearing surface under the machine tool, and if properly made will be the least liable to breakage of the two.

Q. 31. What has the size of the driving journal to do with the size and weight of the box?

A. The smaller the driving journal can be made, and still be strong enough to bear the load allotted to it, the smaller and lighter the driving box can be made, as the amount of friction will be correspondingly less.

Q. 32. What has the hardness of the journal to do with a box heating?

A. If the driving journal is too hard it will take on a very high polish and oil will not adhere to it so readily and heating is more liable to occur.

Q. 33. What resistance is usually allowed for driving journals?

A. Fifty per cent. above the load they are to carry.

Q. 34. What is placed in the top of the driving boxes?

A. Brasses, called crown brasses. This brass is fitted tightly into the top of the driving box, and is semicircular on the under side to fit the journal.

Q. 35. How is the oil that is poured on the top of the driving box carried to the journal?

A. By oil grooves and holes drilled in the top of the driving boxes.

Q. 36. What aids the lubrication of the journal from beneath?

A. An oil cellar filled with waste packing that fits up against the journal and keeps it lubricated with the oil that runs down from the top of the box.

Q. 37. How are the sides of the box and the shoe, wedge and inside of the driving wheel hub oiled?

A. By oil poured on them from above.

Q. 38. What other material is used to lubricate driving journals besides engine oil?

A. Grease; similar to axle grease, only harder.

Q. 39. How is it applied?

A. It is put in a cellar that is forced up against the journal by springs which raise it up as fast as the grease wears away. A sheet iron netting above the grease, through which it feeds, retards its too rapid use. When the supply gets low it is renewed in the roundhouse.

Q. 40. How is the oil cellar with waste packing held in place under the journal?

A. By bolts passing through lugs in the bottom of the cellar and driving box.

Q. 41. What surrounds the driving boxes?

A. The pedestal jaws and pedestal binders, and above the main rail of the frame. The pedestal binder keeps the driving box tight in the jaws.

Q. 42. Why is a little space allowed on a new engine between the inside of the driving wheel hub and the box?

A. To avoid the excess of friction that would be caused by the box rubbing if they fitted tight. In time the wear becomes considerable and gives the engine too much lateral motion.

Q. 43. How are the wedges and shoes oiled with hard grease in cellars?

A. The same as if engine oil was used in the cellars.

Q. 44. Why should the pedestal jaws be held tight by the binder?

A. To prevent the box pounding in the jaws.

Q. 45. What is the driving box shoe?

A. A straight liner fastened to the pedestal jaw at one side of the box.

Q. 46. What is the driving box wedge?

A. A tapering wedge-shaped liner placed next to the pedestal jaw on the opposite from the shoe. This wedge is made to slip up or down the side of the box as desired to take up any lost motion that may arise from the

wear. One bolt, or sometimes two, fastened to the bottom of the wedge pass through the pedestal binder, and by means of a set nut on top of the binder and jam nuts under the binder the wedge may be secured at any desired place.

Q. 47. What effect has a bad driving box pound on a locomotive generally?

A. A very injurious one. It loosens the bolts and joints in different parts of the engine, and causes undue strain that will often result in breakage of some part of the engine.

Q. 48. How should a wedge be adjusted?

A. It should be loose enough to allow the driving box to work freely up and down in the jaws and, at the same time, not loose enough to cause the box to pound. Experience is the best teacher in adjusting a wedge. Put the wedge up as high as you can force it with a short bar and then pull it down a little, say ⅛ of an inch; this will allow room for the box to move up and down enough unless the track is very rough, when it may be necessary to have the wedge a little looser in order to avoid its sticking or, more properly speaking, the box sticking, as it is always the box and not the wedge that sticks.

Q. 49. How should an engine stand to set up a wedge?

A. On straight, level track. Running the wheel which has the wedge to be set up against a block on the wedge side will crowd the box against the shoe and give all the slack obtainable. If the engine is fast to a train, the lost motion can be taken up by pulling or pushing against it in the desired direction.

Q. 50. What is the best position to place the pin to set up a wedge?

A. On the top quarter.

Q. 51. If a wedge bolt was broken, how could the wedge be held in position?

A. It might be possible to put a couple of washers around the wedge bolt on the binder and screw the set nut over the break, or it might be necessary to block under the wedge and on the binder, or on top of the wedge and under the main frame.

Q. 52. What is to be done in case of a stuck wedge?

A. Loosen the set nut and pull it down by tightening the nuts under the binder. Cooling the driving box down, if hot—and it usually is in case of a stuck wedge—will usually help out. Pour plenty of oil on the wedge and the box. If this will not bring the wedge down, run a wheel over a nut. If in a hurry, loosen set nut, oil box freely and, if engine is equipped with water, go. The wedge as a rule will soon come down. A stuck wedge is very hard on track and bridges and should not be run faster than necessary before being attended to.

Q. 53. What causes a wedge to stick?

A. The sides of the box become dry, or the wedge may be adjusted too tight, or possibly it is from both causes. Or the box may become hot and expand, and stick between the jaws.

Q. 54. Aside from the pound involved, what harm comes of running a wedge too loose?

A. The wedge will wear a shoulder on it so that it can not be set up until the wedge is planed off smooth. If by any means it is forced up, it will stick.

Q. 55. Is there anything else that has to do with a driving box running cool?

A. Yes. The proper distribution of the weight of the engine on the driving boxes and engine truck.

56. LUBRICATION.—"What is lubrication and its object?"

Answer.—Lubrication is a method of introducing a lubricant, either liquid or solid, between the journal and its bearing, or between any two wearing surfaces, and the object is to keep the surfaces of the two metals or bearings apart by separating them with a film of lubricant, thereby reducing the amount of friction.

57. CARING FOR HOT BEARINGS ON THE ROAD.—"In what manner would you care for hot bearings on the road, and what kind of oil should be used on hot bearings?"

Answer.—When a bearing gets hot, increase the oil supply, if possible, and be sure the oil reaches the bearing. If an engine truck, tender or driving journal, would examine it at first stop, if time would allow, and pack it if necessary. If driving box was hot, due to wedge being too tight, would pull wedge down. If eccentric was hot, would keep lever hooked up as near center as possible and use valve oil in the strap. If the strap was too tight on the eccentric, would loosen bolts and put in a liner at first stop. If the forward motion eccentric is heating, by having the lever well up in the quadrant a good share of the work is taken on the back motion eccentric. It is not good practice to drop the lever well forward when a forward motion eccentric is running hot, as it increases the work on the forward motion. Care and attention to the bearings will prevent a great deal of trouble due to hot bearings. This is where an ounce of prevention is worth a pound of cure. Use engine oil on all bearings, but if the bearing is very hot, valve oil should be used, and when the box is reported at the terminal to be repacked the sponging that has been saturated

with valve oil should be removed and the oil holes cleaned out, especially in cold weather.

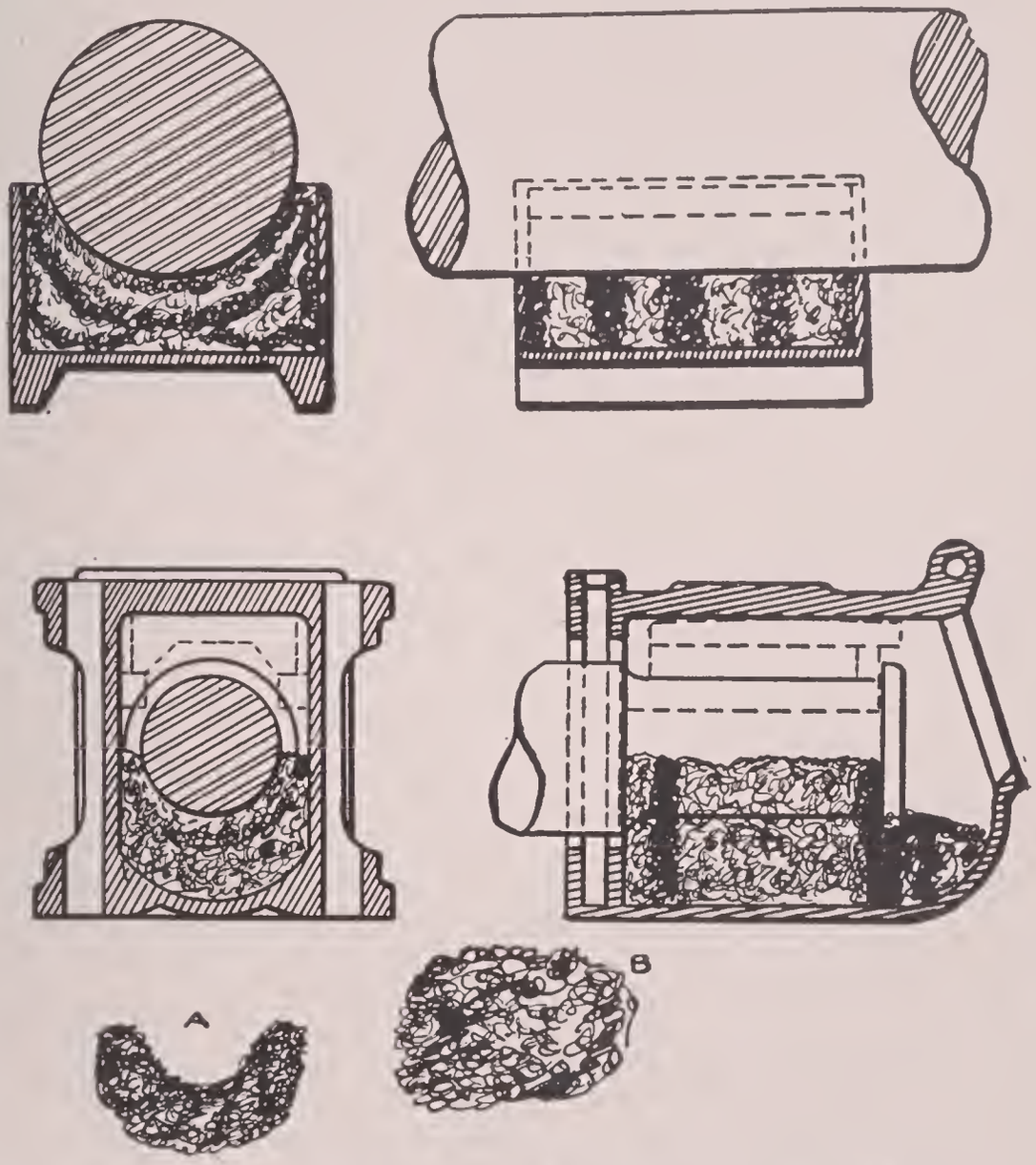
58. Effect of Temperature on Lubricating Qualities of Oil.—"At what temperature does engine oil lose its lubricating qualities? Valve oil?"

Answer.—When its temperature is increased above the flashing or burning point, and the nearer the temperature the oil is to the burning point the less are its lubricating qualities. Engine oil usually burns at a temperature of 380 to 400 degrees F. and valve oil at 680 to 700 degrees F.

59. Successful Lubrication.—"What examination should be made by the engineer to insure successful lubrication, and how should feeders of oil cups be adjusted?"

Answer.—To successfully lubricate bearings on a locomotive, all the examination necessary is to see that the oil holes are opened and a sufficient amount of oil is given the bearing, just enough to properly lubricate them and prevent cutting. The sponging in the driving box cellars tender truck boxes and engine truck cellars should be saturated with oil and have enough elasticity to remain in contact with the journals. The top of the driving and engine truck boxes should be packed with a good quality of cotton waste, well saturated with oil, and this packing should not be disturbed except when absolutely necessary, and in case of its removal from the top of the boxes, care should be exercised to prevent the dirt from entering the oil holes and getting on the bearing. It is advisable to have the ends of the packing or sponging turned down at the edge of the cellars in driving and engine truck boxes, to prevent the waste from working in between the journal and the brass, forming what is

known as "waste grabs." Keep the packing from becoming glazed or hardened in the cellars, and there should be no trouble. Driving and engine truck cellars are often packed as shown in Fig. 1 and give very satisfactory re-



Method of Packing Driving and Engine Truck Cellars.
Fig. 1. Upper figure. Fig. 2. Lower figure.

sults. Tender truck boxes are run most successfully when packed as shown in Fig. 2. The loose ring of saturated waste *A* is put at the back end of the box, and serves to keep the dust or dirt out of the oil. The spong-

ing *B* should be placed between the ring first applied and the collar of the journal, but should never extend quite up to the center of the journal, and this part of the sponging should be built up square with the edge of the collar, without any thread contact with the waste that is put in the front of the box and at the end of the journal to hold the sponging in place. This method prevents the collar of the journal from pulling the sponging from the back of the box. Feeders of all oil cups should be adjusted to feed as small an amount of oil as will run the pins cool, but at the same time should be a constant and positive feed. Otherwise, if gauged too closely, the supply may not reach the bearing at the proper time and in sufficient quantities, and trouble will result. For the cylinders, use dry steam and set the lubricator feeds to suit the speed and service, and in accordance with the size of cylinder. It is advisable to just crack the joint of the throttle valve open enough to prevent smoke and gases from being drawn into the cylinders and steam chest when drifting, and you will be reasonably successful in lubricating your engine.

60. Grease Cellars on Driving Boxes.—"With an engine equipped with grease cellars on driving boxes, how would you know there was sufficient grease in the cellar to make the trip, and if it needed packing out on the road, how would you proceed to pack it?"

Answer.—If you will observe closely you will find that there are two indicators that are attached to the follower plate and extend through the bottom of the cellar, and are for the purpose of indicating the amount of lubricant in the lubricator or grease cellar, and also to show that the grease is being fed to the journal, front and back. When the top part of the ring on the indi-

cator is flush with the bottom of the cellar, it is then time to have it repacked. Examine this before you leave the terminal, but do not get uneasy, as they only have to be repacked every 30,000 to 50,000 miles. If you need to pack a cellar out on the road you can easily accomplish it by removing the end plate on the cellar, which is held in place by two small bolts. Then insert hooks in the eyes of the indicators and pull them down as far as you can; secure them in that position and you will find that the follower plate will be flush with the lower edge of the opening in the end of the cellar. A cake of lubricant or grease should be about one inch thick and two and one-half or three inches wide, and cut in length to fit inside of cellar. Place the first cake to one side of the cellar on top of the follower plate, and the second to the opposite side, then fill the space in the middle with a third piece, put on the end plate, release the indicators and the spring will force the grease up to the journal and you are ready to go.

If you anticipate a job of this kind, have the cakes of lubricant ready, firmly packed, of the right size and free from dirt.

61. Grease Lubrication.—"On the latest type of engine we had for pin lubricant the grease in cup instead of oil. Some of the engineers contend that two or three turns of the compression plug is sufficient. Others say to screw down on them until you see the grease show up around the collar of the pin. I would like to hear from you on this question."

Answer.—If the brass has been taken down it is good practice to screw down on the plug until the grease shows up at the collar, that you may be sure that the pin is properly lubricated in starting out, but if the brass has

not been reduced or taken down the pressure exerted by one or two turns of the plug is sufficient to lubricate the pin for 100 or 200 miles, and less grease will be wasted and the cup will not require filling so often. Best results are obtained when the plugs are screwed down just before leaving a terminal, as the stored-up energy will feed the grease to the pin and a turn of the plug will force out a piece of the grease through a ¼ or ⅜-inch hole about 6 or 8 inches long. If the plugs are screwed down several hours before starting on the trip the energy of the grease in the cup is expanded before it is needed. One or two turns of the plug before leaving will give you better service.

62. Using Water on a Hot Pin.—"What is the objection to using water on a hot pin where grease is used?"

Answer.—There is no real objection to using water on a pin if the grease is of a soft nature, that is, fed to the pin with a plunger in the grease cup, but if a hard grease is used and is forced through the hole in the strap and brass by pressure produced by screwing down the plug, the water will wash off the grease from around the collar of the pin and the grease will not stay between the brass and pin as well when water is used. This grease is similar to a bar of yellow soap, and is made of caustic soda or lye, valve oil and tallow. When the pin is run in water, grease is washed off or made into a suds that has not sufficient consistency to keep the metals apart. You will notice that on a trip in a hard rainstorm the grease will work out faster and the pin run hotter than when the weather is dry.

63. Engine or Signal Oil for Valves or Cylinders.—"Why should engine or signal oil not be used

in valves or cylinders, and at what temperature does engine and valve oil lose their lubricating qualities?"

Answer.—Because engine and signal oils will burn at a lower temperature and are not made for lubricating hot surfaces. When low test oils are used they burn and gum the strips on valves and rings and serve to choke the nozzle. Use the oils to lubricate the parts they were intended for. Engine oil will lubricate up to about 300 degrees, and valve oil will stand a temperature of about 500 degrees without losing its lubricating properties.

64. Adjustment of Dope Cups.—"How do you adjust dope cups on rods, and is it usual for pins to run warmer when using dope?"

Answer.—There is no adjusting on grease cups where a hard grease is used on rods, other than to slack jamb nut and screw down the plug, usually a turn or a turn and a half of the plug will force enough grease to the pin for a run of from 100 to 150 miles on main pins, and proportionately less for siderods. This should be one of the last things done before leaving a terminal. If in a heavy rain-storm the rain will wash the grease from around the collars and they may need more frequent attention. It is usual for pins to run at a little higher temperature when using grease than when using oil as the friction is greater, due to the sticky layers of grease on the pin and brass.

65. Effect of Too Much Pressure in Grease Cups.—"What effect does too much pressure in grease cups produce?"

Answer.—Pins will run warmer and grease will be forced out around collars and pins and wasted. More work for an engineer if he is required to fill the cups and increased cost of lubrication.

66. Fitting Driving Boxes.—"How would you fit a driving box on an engine weighing 200,000 pounds? Our superintendent of motive power claims to bore them 1-64-inch larger than the journal and let them go without fitting."

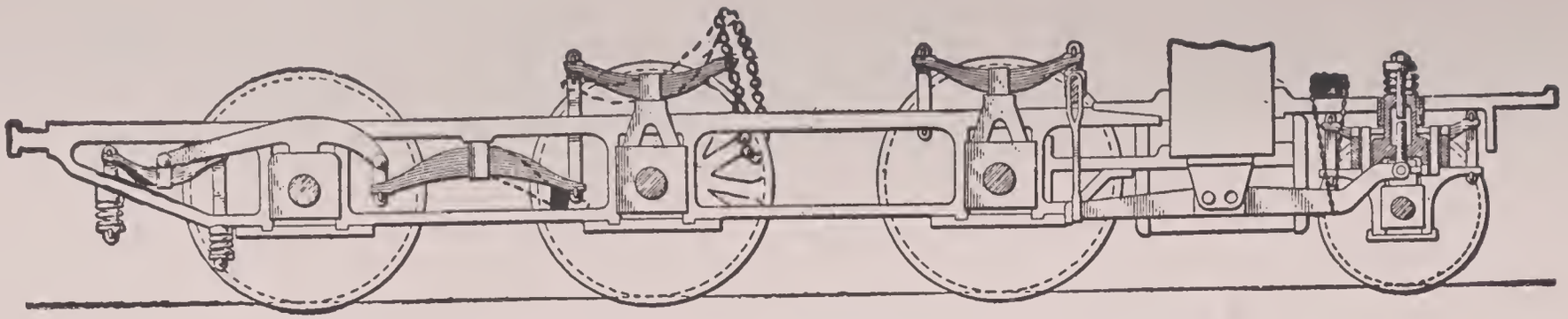
Answer.—It is common practice to file out the crown of the brass about 3 inches wide and file or scrape to a good bearing on the sides. The weight on the box will soon bring the bearing down on the crown. We have seen brasses bored out 1-64-inch larger than the journal and holes bored in the brass for babbitt and then bored out, leaving the babbitt spots higher than the brass, and they run good without fitting the brass to the journal. Your superintendent no doubt is successful in employing this method, and if the engines are properly broken in and run good he is saving expense of fitting. This is not the general practice.

67. Treating Journal Bearings.—"Is it good practice to put sulphur on a hot journal? What would you recommend to bring a driving box down to a bearing after it has been very hot?"

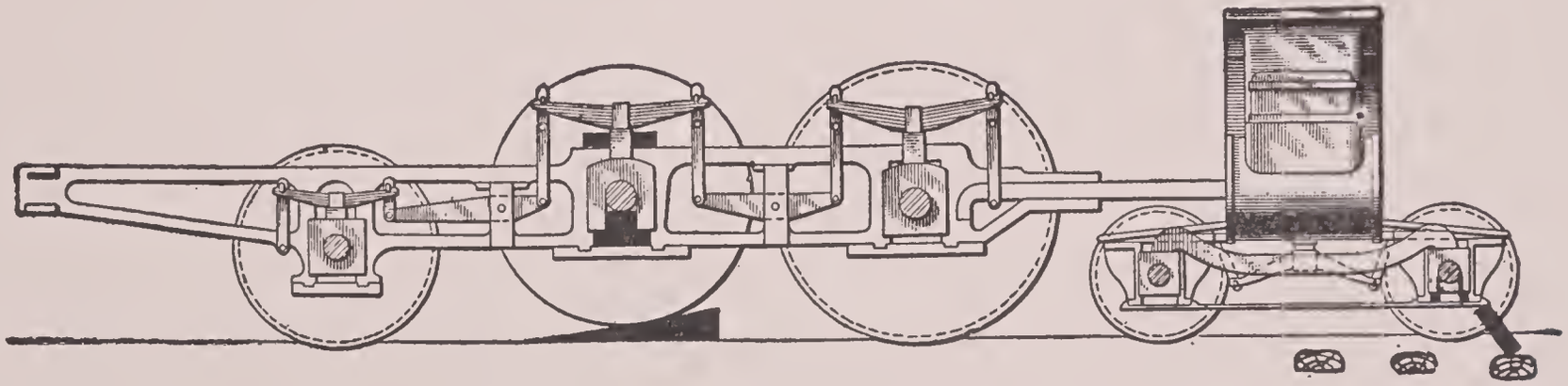
Answer.—Yes; use sulphur with oil, graphite and oil, or powdered mica. They are all good to assist in lubricating an irritated bearing and getting it down to a smooth surface. If the box would not run cool after a fair trial of the above treatment, would recommend that the wheels be dropped, journals turned, and boxes bored out and refitted.

68. Stuck Wedge.—"If a wedge was stuck, in what manner would you proceed to get it down?"

Answer.—Loosen the jamb nut on the wedge bolt on top of the pedestal or binder brace and pull down on the wedge bolt. If the driving box was hot, would cool



Method of Pulling a Driving Spring into Position with a Chain.
Also indicating how front end of long equalizer can be chained up when Bissel pin is broken.



Showing how to Raise Wheel to Block for Broken Tire, or to raise Engine Truck with Fulcrum Block to replace Brass in case of a Hot Engine Truck Bearing.

it off first. If the wedge did not come down easily would run driver over a good sized nut. By cooling off the box and putting a tension on the wedge bolt and oiling the wedge good, the box will often get loose in running to the next stop. There is no such thing as a stuck wedge. It's the box that sticks on account of the wedge being set up too tight. Lack of oil between the box and the face of the wedge, or the expansion of the box from heating causes the box to stick.

69. Setting Out Packing Rings.—"How should the packing rings be set out?"

Answer.—If engine is equipped with spring cylinder packing remove cylinder head and follower. Use calipers, or a stick if you do not have them, to keep piston central in cylinder, loosen jam-nuts and put tension on the springs to hold packing rings out against the cylinder walls. After adjusting, caliper or measure again and know that the piston is in the center of cylinder before or when the jam-nuts are tightened. Proper adjustment depends entirely on your judgment. If the packing is set out too tight it will absorb the power of the engine and may ruin both the packing ring and the cylinder. On the other hand, the packing should be tight enough to prevent the escape of steam past the packing rings, which would result in a waste of steam and loss of power. If snap rings are used they should be turned from a ring about three-sixteenths of an inch larger than the diameter of the cylinder when applied, but if worn they may be peined out with a hammer to fit the cylinder. When applying new rings the sharp corners should be rounded off to prevent the sharp edge from cutting cylinder walls.

DRAFT APPLIANCES AND THEIR TROUBLES.

Question 1. How should a displaced petticoat pipe be readjusted?

Answer. The petticoat pipe is used to obtain an even draft over the whole of the tubes. If too high, the most of the draft passes through the lower rows of tubes and so pulls upon the fire at the front end. If too low the strongest draft is through the upper rows of tubes, the pull being at the rear end of the firebox. Thus the petticoat pipe displacement is easily detected by the action of both the fire and the tubes choking where the draft is smallest, by ashes and cinders.

Hence it is apparent that with an excessive draft through the lower rows of tubes, the petticoat pipe should be lowered; and raised for an excessive draft through the upper rows.

Q. 2. Should a diaphragm or deflector plate on the smokebox become misplaced, how may it be readjusted?

A. The purpose of the diaphragm in the front end is the same as the petticoat pipe: to produce a uniform even draft through the grates and tubes. By the adjustment of the lower edge of the diaphragm uniformity is obtained. The diaphragm is a separate sheet from the main body. When the front end in its present form was first introduced, the diaphragm, (or this lower sheet) was movable and could be raised and lowered by levers in the cab under the control of the engineer. Now it is bolted in such a manner to the main plate that a limited amount of motion is allowed.

The diaphragm displacement is indicated the same as the petticoat pipe by the uneven action of the draft upon the fire. A collection of cinders in the tubes through which an insufficient current of gases pass to keep them clear is another indication. The diaphragm being too high causes an excessive draft through the top rows of tubes, if too low, the same with the lower rows.

If there be an excessive draft through the upper rows and at the rear of the firebox, the diaphragm should be lowered. If the excessive draft is through the lower rows, it should be raised.

General directions for the adjustment of the diaphragm or the petticoat pipe for setting to the desired position are not practicable, because it depends upon the type of engine and also the service it may have to perform. The quality of coal also is a factor.

Q. 3. If the netting should become clogged or broken, what should be done?

A. Netting becoming clogged interferes seriously with steaming sometimes; besides the danger of a fire "blow-back" into the cab.

Clogging is usually caused by an excessive amount of oil in the cylinders. Where automatic oilers are it is less likely than where the cylinders are lubricated from cups in the cab. With this style lubricator, the throttle opening immediately after the oil enters, is liable to throw the oil out at the exhaust nozzle, spattering the netting.

Oil clogging can usually be overcome by vigorous tapping. Should the netting have been cut or worn away and holes are in it, there is danger of large sparks being thrown into the air, sometimes causing fires. To avoid this the engine should be worked as easily as possible when running through sections where the danger of start-

ing fires is greatest. The netting should be replaced upon arrival at terminal.

Q. 4. With a broken front what should be done?

A. This accident seldom occurs, and is usually the result of a hard blow, and other damages generally result from such a blow. A broken front may be repaired by being replaced with boards held by the studs and nuts which were used to secure the front.

Boarding is however, only serviceable temporarily owing to danger of burning by heat and cinders in the smoke box. However, it could be made to answer until reaching a terminal but the engine must be worked easily.

Q. 5. What are the probable causes when exhaust is apparently coming out of one side of stack?

A. The exhaust nozzle may be set so high that steam does not properly fill the stack. Or if the petticoat pipe or the nozzle is out of line it produces the same result.

Q. 6. What would be the effect if the steam did not properly fill the stack?

A. It lowers the steaming of engine and the vacuum in the smoke box becomes irregular. The reason being that the blast produces only a partial vacuum in the smoke box by induction, the same as a jet of steam in an injector will lift water. Should the jet not fill the stack, the vacant space allows the gases to flow sluggishly the result being that the vacuum is lowered considerably. Hence it is important that the size and portion of the exhaust nozzle relative to the height and diameter of the stack should be properly adjusted.

7. FRONT-END APPLIANCES.—"Name what adjustments can be made to the different appliances in the front end of a locomotive and the effect of changing each on the fire."

Answer.—The Master Mechanics' standard front-end arrangement consists of a diaphragm, petticoat pipe, exhaust nozzle, and netting. The adjustments are to raise and lower petticoat pipe and diaphragm, and increase or decrease the diameter of the nozzle. The diaphragm is an apron extending downward from above the top rows of flues and usually forward to or in front of the exhaust pipe, and is for the purpose of equalizing the draft on the fire. Raising the diaphragm causes the fire to burn most in the back end of the box, and lowering it causes the fire to burn most at the front end of the firebox. If you get it in position to burn the fire evenly on the grate surface and utilize the heating surface of the flues, you have done all you can with it. The petticoat is for the purpose of regulating the draft on the fire; it is usually made in two pieces, the lower part having the flare is called the pipe, and the straight part, or top, is the sleeve. Now, you can see if this pipe and sleeve extended from the base of the stack to the bottom of the smokebox, that there would be very little if any, draft on the fire, but by moving the top part or sleeve down and the bottom part or the pipe up above the top of the nozzle, the draft is increased within certain limits. Therefore, raising the pipe or lowering the sleeve increases the draft, and raising the sleeve and lowering the pipe decreases the draft. The nozzle, petticoat pipe and stack are in the same relation to the front-end arrangement as the tubes and nozzles are in the injector. Both are induced currents, only one is for water and the other for steam and gases. Decreasing the diameter of the nozzle tip will sometimes increase the draft on the fire, but as it also increases the back pressure in the cylinders, nozzles should be bushed or reduced only as a last resort.

8. Regulating the Draft in Front End of Engine.—"I wish you would inform me how the draft should be regulated in the front end of an engine with only a petticoat-pipe sleeve and hangers in the front end, and how the sleeve and petticoat-pipe should be handled to increase draft near the flues, or to increase draft near the firebox door. Can you regulate the draft with the petticoat-pipe or sleeve, and must you use one or both for this purpose?"

Answer.—If the front end has no diaphragm in it, lowering the sleeve will give more top draft through the flues. This will reach farther back and cause the fire to burn better or increase the draft at the back end of the firebox near the door. Raising the pipe will increase the draft through the bottom flues and cause the fire to burn more near the flue sheet. Lowering the pipe will decrease the draft near the flue sheet. After you get the fire burning evenly on the grate, if the draft is not strong enough to burn the fire so the engine will steam freely, the draft may be increased by moving the pipe up and the sleeve down. When increasing the draft after you get the fire burning evenly, both the sleeve and pipe should be used. If only one is moved you will get the fire burning evenly on the grate surface again. The more you raise the pipe and lower the sleeve the stronger will be the draft, and the more you lower the pipe and raise the sleeve the lighter will be the draft on the fire.

9. Petticoat Pipe Down.—"What would you do if you were out on the road and the exhaust nozzle came down?"

Answer.—We presume you mean a petticoat pipe instead of a nozzle. If we could not put it in place, would reduce train, get into terminal and report it, but if at

an outside point would try and put it where it belonged, after the fire was drawn. It's almost impossible to adjust a pipe in the front end of an engine with a fire in the box. unless the adjustment can be made from the outside.

10. Effect of Lowering Diaphragm.—"What would be the effect of lowering the diaphragm on a locomotive? That is, will it make a stronger draft on the fire or will it just cause the draft to be stronger in one place, that is, next to the flue sheet? Some claim that by lowering the diaphragm it contracts the opening and consequently the air passes through the grates and flues at a higher velocity and therefore burns the fire more fiercely.

Answer.—The diaphragm is for the purpose of regulating the burning of the fire. Raising it causes a stronger draft in the back end of the firebox and through the upper flues, and lowering it causes a stronger draft in the front end of the firebox and the lower flues. In order to obtain the benefit of the heating surface of the flues and the firebox the diaphragm should be adjusted to burn the fire nearly even on the grate surface and cause an even draft through the flues. As water always boils upwards it is sometimes an advantage to have the draft slightly stronger through the lower flues. After the diaphragm is adjusted to obtain the above result it should be kept in that position. If the engine does not steam and we desire to increase the draft through the grates and all the flues it should be done by the adjustment of the petticoat pipe and sleeve. Although lowering the diaphragm would contract the opening and increase the velocity of the gases through the lower flues and front end of the box, it would be a detriment to the steaming qualities of the engine as we would lose the heating surface of the upper flues. Raising the bottom part of the pipe above

the nozzle tip or lowering the top part or sleeve from the base of the stack will increase the draft; raising the sleeve and lowering the pipe will decrease it. Observe Fig. 1 with a pipe and sleeve that extends from the base of the stack to the base of the exhaust pipe, the dotted and broken lines representing the steam passing to the stack. This is not a very large opening for the exhaust steam to expel the smoke and gases from the front end; as they are not thrown out, the vacuum is not formed

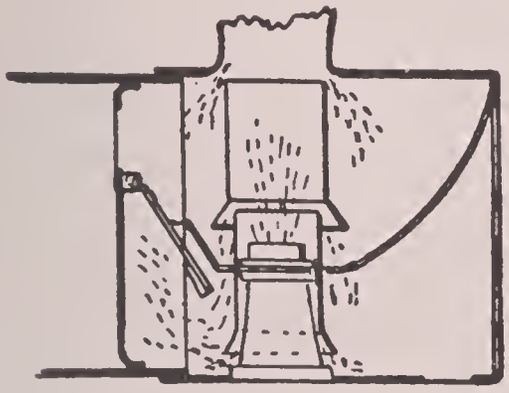


Fig 1.

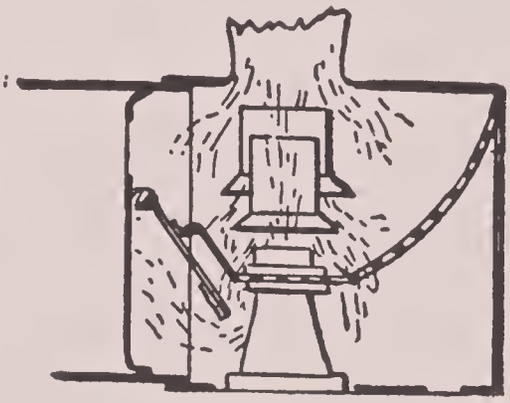


Fig. 2.

and the air is not drawn through the grates to fill the vacuum in the front end. In Fig. 2 we have the pipe raised above the nozzle tip and the sleeve lowered from the base of the stack so that the exhaust steam will expel the gases from the front end and a greater volume of air will flow through the grates and fire, promoting combustion. Consider that the nozzle, petticoat pipe, sleeve, and stack should do business in the front end the same as the tubes and the nozzle of the injector, and adjustments can be obtained that will be satisfactory. If the draft cannot be made strong enough in this manner then the nozzle should be bushed, but on account of the effect of the back pressure in the cylinders this should only be

done when changing the pipe or sleeve will not produce it.

11. Exhaust Strongest from One Side of Stack. —"What does it indicate when the exhaust issues strongest from one side of the stack?"

Answer.—If the engine has been in service and the exhaust has filled it evenly, the indications are that the petticoat pipe is loose or tipped, directing the exhaust to one side of the stack. If the engine has recently passed through the shops, it may be that either the petticoat pipe, exhaust pipe, nozzle tip, or stack are not in line with one another.

12. Bridging Exhaust Nozzles.—"What difference does it make whether you put a bridge in an exhaust nozzle crosswise with the flues or parallel with them? A bridge is used here to spread the exhaust steam to fill the stack so the engine will burn her fire."

Answer.—A bridge placed in a single nozzle has the effect of reducing the area and increasing the back pressure in the cylinders. Spreading the steam to fill the stack in this manner would have a tendency to further increase the back pressure, as it has been found that reducing the choke or small diameter of the stack caused back pressure the same as reducing the nozzle. If the stack is out of line to one side or the other, placing the bridge parallel with the flues would cause the steam to fill the stack and produce a greater vacuum than if the stack was not filled by the exhaust. Should the stack be out of line, either forward or back of the nozzle, then it would be more beneficial to place the bridge crosswise of the flues, but it would be better to have the nozzle and stack put in line so that the expansion of the exhaust steam would fill it evenly. Bridging a nozzle is usually creating one defect to remedy the other.

13. Pull on Fire-Door.—"What causes a pull on the fire-door?"

Answer.—Dampers closed, ashpan full of cinders, grates without sufficient openings for admission of air, too heavy a fire and badly clinkered fire, or insufficient opening of dampers in ashpan, all tend to produce a pull on the firebox door. The exhaust steam passing up through the stack expelling the smoke and gases from the smokebox creates a partial vacuum in front end to stack. The air supply should come up through the grates and fire. When the supply is insufficient the pull on the door results.

14. Height of Smoke-Stack.—"Why is it that on our small locomotives they have such long smoke-stacks and on the large ones so short a stack? I claim that on our small locomotives, having a long exhaust pipe, the steam from the exhaust would not expand and fill the smoke-stack if it was only from 24 to 26 inches long, and on the large locomotives we have short exhaust pipes and short smoke-stacks. I claim that the reason for this is due to the large boiler and that the steam from the exhaust pipe exhausts into a petticoat pipe and expands, and thence to the smoke-stack."

Answer.—The reason for the small engine having a long stack and a large engine having a small stack is that the height of stack is governed by the limit of tunnels, bridges, roundhouses, etc. Experiments have shown that there is nothing to compensate for length of stack in promoting efficiency of the front end, consequently as long a stack as can be used is desirable. The arrangement of the front end is usually based on formulæ on which the diameter of front end is a factor, so that the larger the boiler the higher the nozzle. The short stack

on large engines is so made only to give proper clearance and is compensated for as much as possible by use of petticoat pipes.

15. ENGINE DOESN'T STEAM.—"Will you kindly give me your advice and the benefit of your experience on the following? The engine came here new last August with a brick arch and up to some time ago did first rate. She has not been doing so well lately, and have reported work as follows: 'New brick arch, bore out flues, clean out nozzle, etc.' She had been steaming pretty well before this work was done, but tore the fire all to pieces, especially after being cleaned, knocking it through to the pan. They had no new brick to put in, so took the remains of the one out entirely. They found the nozzle coated about ¼ of an inch and cleaned that out. Now she does not steam nearly so well and burns all the coal you can pile on. Should the diaphragm be altered, and if so, higher or lower?"

Answer.—An engine out of the shop six months should be in good condition if running in a locality where there is good water used, providing that the flues and firebox do not leak and the boiler is free from mud and scale. You have the same amount of heating surface, and with the valves and cylinder packing tight the engine ought to do good work. Although the brick arch is considered as an aid to combustion, the engine can be made to steam well without one, but it is usually necessary to lower the diaphragm about 3 inches when the arch is removed, providing that the front end was properly adjusted to steam with one. Lower the diaphragm to increase the draft in the forward end of the firebox and through the lower flues and raise it to increase the draft in the back of the firebox and through the upper flues. Change it

until you get the fire to burn evenly on the grates. Would suggest that the exhaust pipe be examined and ascertain if it is not choked up below the tip, thereby reducing the area of the exhaust pipe which, with the uneven draft you may have, tears holes in the fire. See that the stack is in line with the nozzle, that the gasket between the exhaust pipe and cylinder saddle is not cracked or blown out, and that the exhaust from the air pump is directed up the stack and not against the pipe or smoke arch, thus destroying the vacuum in the front end. If the fire burns a dull red have the steam pipes examined for leaks. Go right after her and you will make steam.

LUBRICATORS AND THEIR TROUBLES.

Q. 1. If a cylinder lubricator will not work, what should be done?

Answer.—The lubricator disconnected and the cylinders oiled through the feed pipes the same way as the old-fashioned cylinder lubricators.

How to do it depends upon the style of lubricator used. Usually it will be possible to disconnect it so that the work can be done as described.

With a Nathan lubricator, if it stops feeding oil because of breakage of the glass or any other cause the valves which cut off the flow of oil through the glass or passage affected should be closed, and that will not then interfere with working the rest of the lubricator.

Special tallow cups are provided on that type of lubricator, which may be opened and used in the same way as the old-fashioned cab oilers, when the engine is on a down grade or when drifting with the throttle closed.

This also may be used at any time to supplement the supply of oil to the cylinder, as with common non-automatic lubricators. With some changes in detail of operation and arrangement this method may be used with all sight-feed automatic lubricators.

Q. 2. What causes irregular action of an automatic sight-feed cylinder lubricator?

A. If choke plugs fit too loose, or feed-holes are too large, they may result in an intermittent feed. This hole should be not more than 1-32 inch in diameter. An obstruction in the equalizing tubes causes an irregu-

lar action, so they should be kept free and clean and the choke plugs tight.

Q. 3. What should first be done when a lubricator does not work?

A. The bottom cocks opened and a full head of steam turned on to blow it out. Should this not put it in working condition, the sight feed glasses should be taken out and the feeders at the bottom examined to ascertain if they are clean. Should this fail it should be disconnected.

Q. 4. Should a (Nathan) lubricator fail to feed, although the feed glasses fill with water while not working, and all the water leaves the glass as soon as you try to use the feed, what is probably the trouble?

A. The trouble may be "caused by not having full steam pressure on the lubricator when the engine was moved out of the round-house. The water valve was opened, but not the steam. In this condition there was a direct opening from the lubricator to the steam chest through the water valve drawing the condensed water from the condenser and then siphoning the oil through the water tube out of the oil chamber. This will cause the water from the sight-feed glasses, together with any oil that may be on top of the same, to be drawn into the oil chamber. This will last until the oil chamber is solid full, then the feed glasses will fill up with water again, and if the condenser has in the meantime regained condensed water, the cup will feed oil again. The remedy is to open the steam valve full before the engine is moved.

Q. 5. If the water gauge glass breaks, what should be done?

A. If the fittings are not supplied with automatic self-closing valves, this minor accident may cause serious

injury to enginemen, especially the fireman, because of the broken pieces of flying glass. The cocks should be closed at top and bottom of fitting, that prevents escape of steam. Then use gauge cocks to learn water level until reaching terminal.

Q. 6. What indication of a defect in the water glass is usually seen?

A. The surface of the water in the glass is constantly rising and falling when engine is in motion and if it becomes stationary at any time it indicates that the opening at bottom of the glass is clogged more or less.

Q. 7. If the surface of the water moves up and down when the engine is moving does it indicate positively that both top and bottom openings of the glass are free?

A. No. The top opening may be nearly or entirely closed, and if the opening at bottom is clear the water continues to rise and fall in the glass, although it does not correctly register the water level in boiler. Because of this the water gauges should always be kept free and used frequently to check the water glass indications.

Q. 8. When a water glass is broken how may a new glass be cut to replace it?

A. A piece of hardened steel with a bent point should be used to make a scratch around the inside of the tube. The tube may then be easily broken accurately at the point marked.

Q. 9. What precautions ought to be taken when replacing a broken water glass?

A. If at time replacement is made, the boiler is hot, the packing at ends of glass should be screwed up loosely so there may be no possibility of unequal expansion between the glass and the frame which would cause an ex-

cess of pressure on the glass and so break it. After it has been placed in position it should be allowed to stand sufficiently long to get as warm as when in contact with the heated parts of frame. The upper valve should then be started to allow a little steam leakage into the glass and a considerable amount of condensation to collect at the bottom before the lower valve is started. When the water level indicates about the same as the boiler, the valves should be gradually opened until in their normal working position.

Then the packing glands may gradually be screwed up until all leaking has stopped. But a leak is preferable to screwing the packing too rapidly, because the glass should be entirely free to expand lengthwise and diametrically that it may adjust itself to the normal working condition and be free from strain.

10. THE LUBRICATOR.—"Does the lubricator feed oil to the cylinders of the locomotive, and does it also feed a small amount of the steam with the oil? Will it feed oil to the cylinders at all times? With an engine descending a heavy grade with lever in back motion, will the lubricator feed oil to the cylinders to prevent excessive wear?"

Answer.—When a drop of oil rises through the water in the sight feed glass and reaches the top of the water, it is carried through the choke plug with the steam that comes down through the equalizing tube and is mixed with the oil, forming oil and water in the oil pipe leading to the steam chest when the lubricator pressure is greater than the steam chest pressure. If the steam chest pressure is the greater, the oil and water is then held in the pipe in suspension until the steam chest pressure is reduced by closing the throttle or by the fluctuations of

pressure, caused by the valve opening the ports for the admission of steam to the cylinders. Then the oil and water is carried to the valve seats and cylinder walls, lubricating them. In descending a heavy grade with engine reversed to prevent excessive wear of cylinders, a water jet or what is termed the "water brake," would be more effective than a lubricator.

11. The Sight-Feed Lubricator.—"Does the oil fed through a sight-feed lubricator go from the lubricator to the valve by gravity, or is it forced down by a current of steam?"

Answer.—Oil that is fed through a sight-feed glass of a lubricator rises to the top of the water in the glass by reason of the oil being the lighter, and the pressure of the weight of the water in the condensing chamber whose level is higher than the level of the water in the chamber above the sight-feed glass. The steam that flows through the equalizing tube forces water from condensation through the hole in the choke plug, keeping the water at a level with the opening. As the oil rises to the top of the water, the water and oil above this level are forced through the choker into the oil pipe leading to the steam chest. When the pressure at the lubricator end of the oil pipe is the greater the oil is carried to the steam chest by the current of steam pressure. Oil being heavier than steam it would flow to the chest by gravity without the pressure of steam, but the movement would be slow. When the pressure at the steam chest end of the oil pipe exceeds the pressure of the lubricator end the oil pipe is sometimes filled with water, forming what is termed a "pocket" for the oil and preventing the flow of the oil to the chest until the pressure is reduced at that end of the pipe. Oil does not flow through the pipe as

it appears in the glass. When the drop of oil rises opposite the hole in the choke plug the steam and water atomizes it and it is mixed in proportion to the amount of oil and water that pass through the choker. The valves and cylinders get oil and water. A sample of this can be easily obtained by disconnecting the oil pipe, starting the lubricator and placing a bucket under the end of the pipe. Various kinds of circulating valves and devices are used to insure a positive circulation through the oil pipes from the lubricator to the chest and maintain lubrication under the varying conditions.

12. Defective Lubricator.—"I filled the lubricator and turned the steam on and opened the condensing valve. The oil ran to the top of the condensing chamber and leaked out at the joint that connects the steam pipe to the chamber, also at the union and globe valve between the lubricator and the steam box on the boiler head. All of these joints were leaking. Please say what was the trouble with the lubricator."

Answer.—As no particular make of lubricator is given, we will assume that it is a Nathan lubricator or one of similar construction. Such being the case it is evident that the partition separating the oil reservoir from the condensing chamber had a crack or a sand hole in it or the plug was loose or leaked; or the pipe leading from the opening of the water valve that extends down to near the bottom of the oil cup was split. Either of the above defects would allow the oil to rise to the top of the condensing chamber, and, if the leakage was greater than could escape through the choke plugs, the oil would naturally rise to the top of the condensing chamber and leak out at the joints as stated.

13. Irregularity of Feed of Lubricator.—"What else might cause irregularity of feed?"

Answer.—Dirt in the lubricator, choke plugs worn too large, equalizing tubes stopped up, or insufficient area of steam pipe to supply steam to the lubricator. Sometimes this occurs when pipes are tapped to a fountain that is too small in its main opening to supply the boiler attachments, such as injectors, air pumps, blower, smoke consumers, etc.

14. Cross-Feed of Lubricator.—"Is it possible for a lubricator to cross-feed and allow all the oil to go to one steam chest?"

Answer.—It is possible for some lubricators to cross-feed, although it does not happen frequently. With choke or oil pipe stopped up on some lubricators the equalizing tube becomes filled with water, and the oil, instead of being forced through the choke plug by or with the steam from the equalizing tube, rises through the water to the top of the equalizing tube in the condensing chamber and is carried over to the equalizing tube on the opposite side and through the choke plug to the oil pipe on the side that has the equalizing tube open, thereby cross-feeding.

This can usually be detected by the sluggish manner in which the oil rises through the water on the defective side of the lubricator.

15. By-Pass Valve on Lubricators.—"What advantage has the by-pass valve, that is, in speaking of lubricators? Explain how it is operated."

Answer.—The advantage of a by-pass valve on a lubricator is that it takes the place of a hand oiler, and in case the feed valve is stopped up or the glass breaks, the valves and cylinders can be lubricated without shutting off steam. When the by-pass valve is opened the oil will flow directly from the oil reservoir through the

by-pass valve to the oil pipe. They can be regulated to feed the same as the feed valves when necessary, but it would not be a sight-feed lubricator when the by-pass valves are being used.

16. Lubricator Siphons into Boiler.—"How does oil from a lubricator siphon into a boiler when a boiler is allowed to cool and the lubricator throttle is not shut off? What is cause?"

Answer.—When a boiler is in service it contains water and steam at a temperature in proportion to the pressure. The steam and water occupy space. When allowed to cool the steam is condensed, and the water, losing its heat, also occupies less space. When this occurs a vacuum is formed in the boiler. Atmospheric pressure surrounding the boiler trying to get in and destroy the vacuum is the cause of the oil siphoning out of the lubricator, and this occurs only when the lubricator is not perfectly tight in all joints. A very slight leak at filling plug, around the gaskets of the oil glass, or packing nut on the feed valve, will admit air enough to destroy the vacuum and allow atmospheric pressure on top of the oil in the cup. The vacuum in the boiler will tend to draw the oil up through the steam pipe above water valve when it is open, and as this passage or pipe extends nearly to the bottom of the oil cup it affords an easy passage for the oil to siphon into the boiler. If the oil cup was absolutely airtight, oil would not siphon out. This is why it only takes place occasionally on certain engines when the lubricators are not absolutely tight.

17. Equalizing Tubes of Lubricators.—"Please explain the use of the equalizing tubes in a lubricator, and if all lubricators are supplied with them. Some lubricators do not seem to have any on the outside."

Answer.—The use of the equalizing tube in a lubricator is to equalize the pressure of steam on the water in the sight-feed glass. The steam enters the condensing chamber and condenses, forming water, and the oil is floated on the water in the oil reservoir of the lubricator and fills the oil pipes leading to the sight-feed glasses with oil. When the feed valves are open, we have the pressure of the steam and the weight of the water to force the oil through the nipple in the sight-feed glass. When you have an equalizing tube that is stopped up or an enlarged choke plug, you have this condition, and when the throttle is closed the oil is forced through the feed valve nipple in a stream. The equalizing tube is connected to the cavity above the sight-feed glass and steam exerts a pressure on top of the water in the glass. This, therefore, equalizes the pressure in the lubricator, and we have the weight of the water in height in the condensing chamber to force the oil out of the nipple, and the buoyancy of the oil causes it to rise to the surface of the water in the sight-feed glass, when it is carried into the oil pipe by the steam that came in on top of the water from the equalizing tube, which forces a small jet of steam and the oil through the choke plug. On some lubricators the equalizing tubes are inside of the condensing chamber, and on others they are on the outside.

18. Effect of Draft on Working of Lubricator. —"Does the draft from an open cab window affect the working of the lubricator? Why?"

Answer. The cold air striking the lubricator will cool it and chill the oil, which retards its flow. If the feed valves are open to feed the proper number of drops, then closing the window allowing the lubricator to get warm, the oil will feed faster, thus causing an irregularity of feed.

19. Miles Run to a Pint of Oil.—"How many miles should an engine run to one pint of valve oil; engine oil; and how would you oil an engine to effect the greatest economy?"

Answer. Just how many miles an engine should run to a pint of valve oil or engine oil depends on the class of engine and the class of service, and how many of the bearings are lubricated with oil, and if the driving boxes are equipped with grease cellars and grease used on the pins.

The proper way to determine a fair amount of oil to use in your service would be to check up the performance sheet and strive to keep above the average. By doing so you will, as a rule, have sufficient oil to keep the bearings cool. To oil an engine with economy it is necessary to first provide yourself with suitable oilers and large cans to hold the supply for the trip. Keep them clean and free from leaks, see that you get the amount of oil you are charged with, and if the engine is of a type that you can oil without moving, place the engine so that the crossheads are opposite each other—as near the back cylinder heads as possible. This will usually enable you to reach the shoes, wedges, driving boxes, eccentrics, etc., on both sides. If you can not do this, oil one side at a time. Place engine on forward center right side and hook lever clear back. Commence at the right back driving box, oiling shoe and wedge, also the main oil pocket in the driving box. Get the oil well over toward the inside of the box, but do not disturb the sponging on top of the driving box. This to insure oil getting to the part of the driving journal that is most exposed to dirt and ashes at the ash pit. The hub of the wheel protects the outside of the box,

and the bearing gets dry on the inside first. Then go forward to the next and oil in the same manner. Oil eccentrics, link motion, rocker boxes and back end of valve stem. Open feeders on guides, but do not fill guide cups so full that they will run over. Oil swabs on pistons and valve stems; oil engine truck, and go to the left side, oiling back to the driving boxes. Then move engine to forward center on left side, leaving lever in full forward gear. This will give you a chance to oil back motion eccentric rod where it connects to the bottom of the link if you were unable to reach it before, and when you oil back to the back wedge on the left side you are through. Then fill the lubricator and feed the oil to air pump, valves and cylinders to get the best results, keeping the water at its proper level in the boiler all the time, and the throttle slightly cracked open to prevent vacuum being formed in the cylinders while drifting. This will insure a good oil record to those who practice it. Shut off all feeders on guide cups, valve and piston rods on arrival at terminal.

STEAM GAUGES.

Question 1. When a steam gauge becomes broken or fails to indicate the actual pressure, what should be done?

Answer. This is a minor accident that is of comparatively little moment. While it is desirable that the gauge should be accurate in order that the enginemen may be able to regulate the fire and run most efficiently, it is quite possible to run safely without any steam gauge at all. The failure of this fixture is comparatively rare, but as it is subject to constant deterioration it should be tested frequently and readjusted to proper indication. If, however, the gauge should be broken as the result of any accident the steam should be shut off from it and the run completed by the indications of the safety valve. Incidentally, the noise of the steam escaping from the top gauge cock should afford an approximate indication of the steam pressure in the boiler. This, however, requires an ear trained by long and close observation.

CROSBY LOCOMOTIVE PRESSURE GAUGE.

This gauge has double Bourdon tube springs, shown in Fig. 1-A. The tube springs are connected at each end by screw threads without soldering, thus insuring tight joints under extreme conditions of heat and pressure. The lever mechanism, which transmits the free movements of these Bourdon tube springs to the index, has

been designed with great care, and so that it may be easily renewed in case of repairs.

Fig 1.

Fig 1-A.

Crosby Locomotive Pressure Gauge.

These gauges for locomotive use are graduated to any pressure not exceeding five hundred pounds per square inch.

Fig. 2. Crosby Single Tube Gauge.

Fig. 2 shows the interior arrangements of a single Bourdon tube spring Crosby gauge. This gauge is designed to meet the demand for a cheaper gauge than the more accurate double tube form before illustrated.

The thermostatic water back gauge shown with single and double Bourdon tube springs in Figs. 3 and 4,

is adapted for use on high-pressure locomotives, especially compounds, which frequently carry a boiler pressure of two hundred pounds or more.

It is well known that when a steam gauge in use, on account of its location, is heated to a temperature of 100° Fahr., and upwards, that there is an expansion of its parts, due to the heat, to such an extent that it will be erroneous in measuring the pressure which it should record. In such cases the parts which materially affect the correct operation of the gauge are the tube springs. It occurs thus: The tube springs having been tested

Fig. 3. Single Bourdon Tube Spring.

Fig. 4. Double Bourdon Tube Springs. Crosby Thermostatic Water-Back Gauges.

and adjusted to a certain movement under pressure in the ordinary temperature of the factory, or where it takes place, will when the same are heated in use to a high temperature lengthen by expansion to such an extent that, when they are subjected to the same pressure, their free ends will move through a larger arc than when they were tested. This movement multiplied by the ordinary mechanism of a steam gauge for transmitting it, causes this increased pressure to appear upon the dial. In such a heated condition of the tube springs,

the error produced is sometimes considerable, being several per cent. greater than the true pressure, thus deceiving the user of steam into the belief that he is getting a less result, in work, from the indicated pressure than he ought. This error can be corrected by suitable mechanism in the steam gauge. Such an one, it is claimed, is internally shown by Figs. 3 and 4. In the ordinary steam gauge, the bar which transmits the movement of the free ends of its tube springs is made of a homogeneous metal, and when the tube springs are affected under heat as above stated, it transmits the increased movement just in the same way that it would transmit the intended or designed movement when the tube springs are cold. Thus the error arises. In this improved gauge the bar is made of brass and steel brazed together, forming a thermal bar, so that, under the influence of high temperatures, it will compensate for the expansion or lengthening of the tube springs and their greater movement thereby under pressure, by retarding simultaneously the motion of the index which records such movement on the dial. The action of this thermal bar is, that its end remote from that where it is attached to the tube springs will droop, or deflect, or move oppositely to the tube springs on account of the action of the temperature upon the two metals composing it, as is commonly understood. This opposite movement retards the index proportionately to the lengthening of the tube springs, as they are both influenced by the same temperature, and thus compels it to keep back to the notation of pressure on the dial where it correctly should be.

In addition to this thermal bar, this gauge has a chamber, so constructed that when filled with water or

other liquid it not only supplies the Bourdon tube springs, connected to it with all that is required, but serves to equalize the temperature about them. This is important. For unless the tube springs are subjected to a heat greater than 212° Fahr., they do not set when in use; and as it is impossible, as made, under ordinary conditions of use, for heat to be transmitted by conduction to such an extent, they are secure from this danger.

This chamber is located in the gauge case so that it has its connection to it and with the boiler at the bottom. Attached to it are the tube springs, the index mechanism, and the dial, the latter upon the bosses; and all are independent of the case and are free from any influence of it under heat, excepting at its immediate point of attachment, which is unimportant.

The chamber of this gauge is filled with a liquid which is not seriously affected by exposure to cold, nor is it injurious to the operation of the gauge. Upon the removal of the cork which is inserted in the inlet of the gauge connection to prevent leakage during transportation, it may be attached to the boiler in the usual manner without a siphon or other device for furnishing water to it.

Should it become necessary again to fill the chamber with water or other liquid, remove the small screw located in the case by the side of the gauge connection, to provide a free course from the inlet in the gauge connection, around through the chamber and tube springs to the open air. Then, holding the gauge so that the inlet will be uppermost, pour the liquid used into it, occasionally shaking and turning it to expel the air and assist the flow of the liquid into all parts of the cham-

ber and tube springs. When they have received about two fluid ounces of the liquid, and it appears at the aperture of the screw removed, they will then be filled. Close this aperture tightly with the screw and the gauge will be ready for use.

The Lane Pressure Gauge is shown by Fig. 5. The improvement in this gauge consists of a bent lever provided with an adjustable link at its head, to which one of the tube springs is attached, the other tube spring being directly connected with this lever. By this plan the movements of the lever and rack, relatively to the two tube springs, can be more readily and perfectly adjusted than by any other method in use in this style of gauge.

Fig.5 . Lane Pressure Gauge.

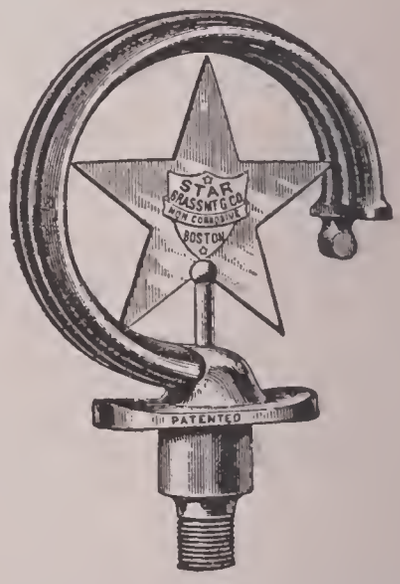


Fig. 6. Star Corrugated Spring.

STAR GAUGES.

In designing a spring tube that will not retain any permanent set after repeated bending back and forth with varying pressure, the manufacturers of this gauge make use of a corrugated tube, as shown in Fig. 6. These

makers also lay special stress upon the point that they have for many years manufactured a non-corrosive movement in their gauges, thus avoiding the injurious results of smoke and gases.

STAR NON-CORROSIVE AND NON-SETTING LOCOMOTIVE STEAM GAUGES.

Two styles of these gauges are illustrated by Figs. 7 and 8. The former (the standard) is known as the double spring Bourdon type and Fig. 8 shows the double spring Lane type.

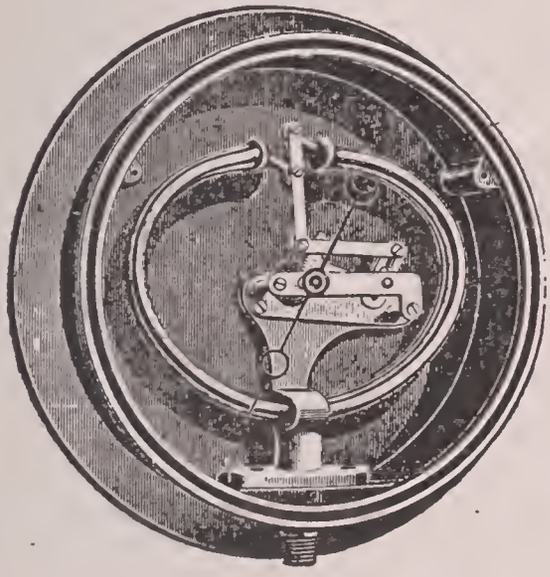


Fig. 7. Star Double Spring Gauge. Bourdon Style.

Fig. 8. Star Double-Spring Gauge. Lane Style.

Each style of gauge is fitted with their non-corrosive movement and corrugated spring tubes.

It is a well-known fact that in all branches of mechanical engineering where lightness, rigidity and strength are required, corrugation is adopted where practicable, in order to give the necessary stiffness without increasing the weight. Hence it is claimed that the

corrugated spring tube is superior to the plain forms. These gauges are fitted with hair springs to take up all lost motion, after the approved practice of all accurate pressure gauges.

ASHCROFT GAUGE.

These gauges have non-corrosive movements and are constructed of Bourdon springs of seamless drawn tubing.

Fig. 9 shows the interior mechanism of the single Bourdon spring steam gauge, and Fig. 10 the same of the double Bourdon spring gauge with the addition of the Lane improvement in attachment of springs to movement as referred to hereinbefore.

Fig. 9. Ashcroft Single Bourdon-Spring Steam Gauge.

Fig. 10. Ashcroft Double Bourdon-Spring Steam Gauge with Lane's Improvement.

In order to provide a gauge that should be accurate, durable and exempt from the annoyance of permanent set of the Bourdon springs, these manufacturers provide a locomotive steam gauge having an auxiliary spring, as shown in Fig. 11. The auxiliary spring feature consists of an independent co-operating spiral spring (*A*) applied to the free end of the single Bourdon tube, which dispenses with the necessity of a sec-

ond tube, and reduces the number of joints subjected to wear and friction between the tube and the segment of the recording movement to two. The Bourdon tube, it should be noticed, is short enough to drain itself and thus prevent damage by freezing.

Fig. 11. Ashcroft Auxiliary Spring Locomotive Steam Gauge

Fig. 12.

Fig. 13.

Ashcroft Double-Spring Standard Locomotive Gauge.

Figs. 12 and 13 illustrate the Ashcroft double spring standard locomotive gauge, the internal arrangement being clearly shown.

The following cuts illustrate a type of Gauge Cock known as the "Baltimore."

It will be observed by reference to the illustrations that the check or retaining valve comes to its seat when the stem and seat of the gauge cock proper are removed.

This valve can be rotated when under pressure, and

also when removing the stem; the act of unscrewing the stem for repairs rotates this valve after it comes to its seat and until it is disengaged from the end of the stem, thus insuring a tight seat after the parts for repairs are removed.

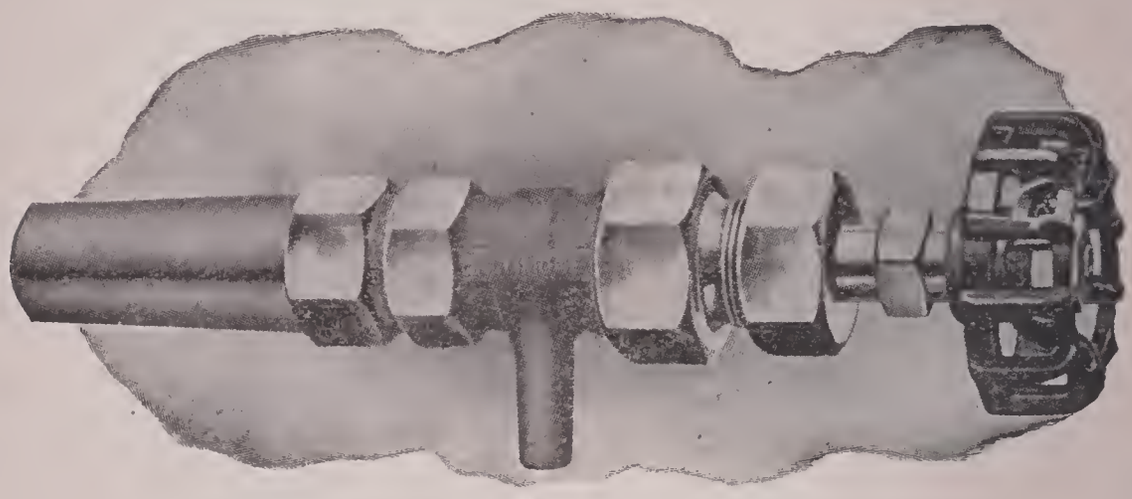


Fig. 14.

The important feature is the removable double seat, which is a plain disc and is seated on both sides. This seat can be made of a material or metal best suited to locations where it is used.

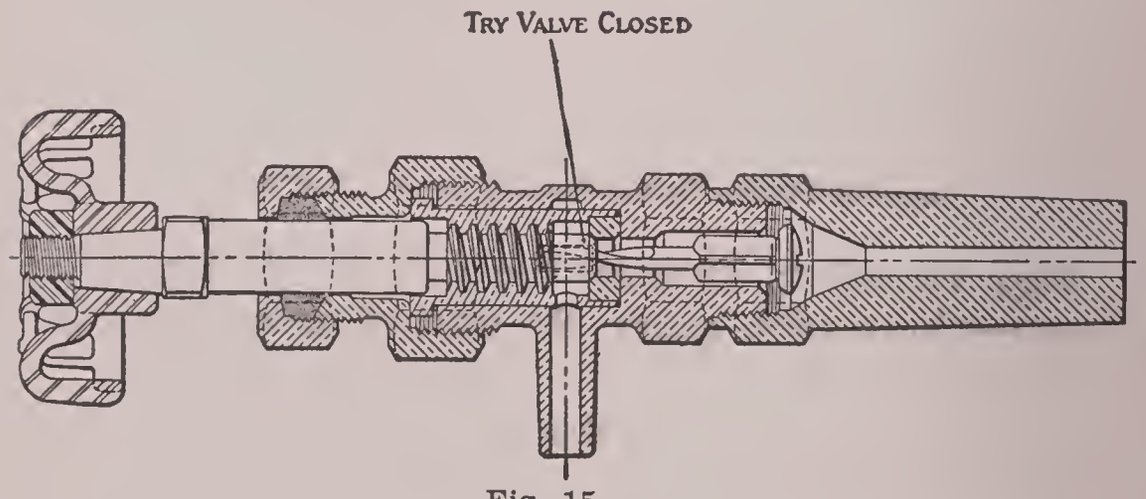


Fig. 15.

Should the sleeve (Fig. 18) become scaled and tight in body, it can readily be made free by unscrewing the cap nut one or two turns and screwing in on try-valve

stem. The small square at the outer end of the try-valve stem is for that purpose. A small wrench may be used to force the stem in and loosen the sleeve in body.

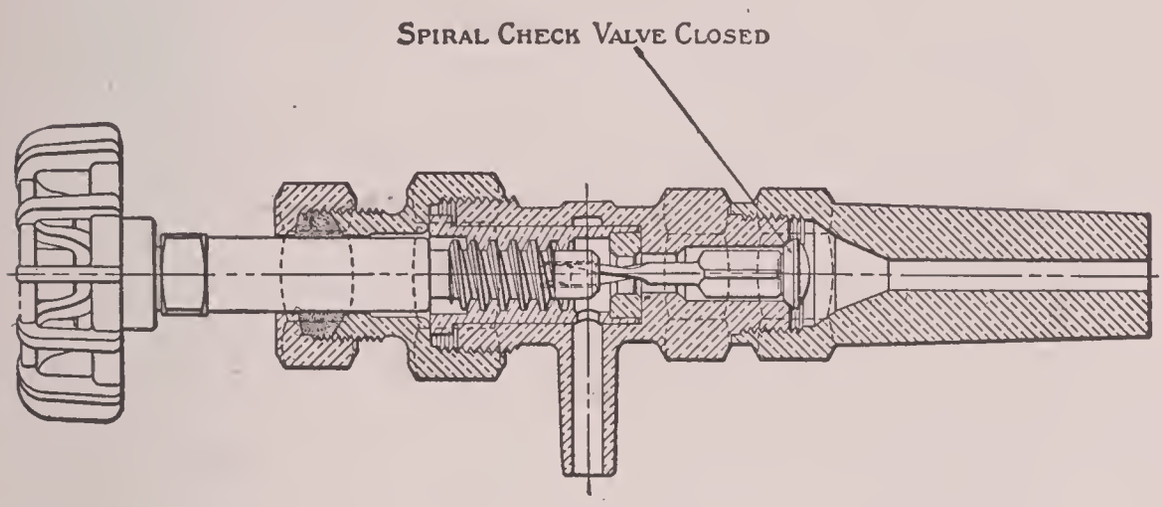


Fig. 16.

Where it connects to body a slot opening is provided in the boiler spud to ensure a free opening at all times to the boiler.

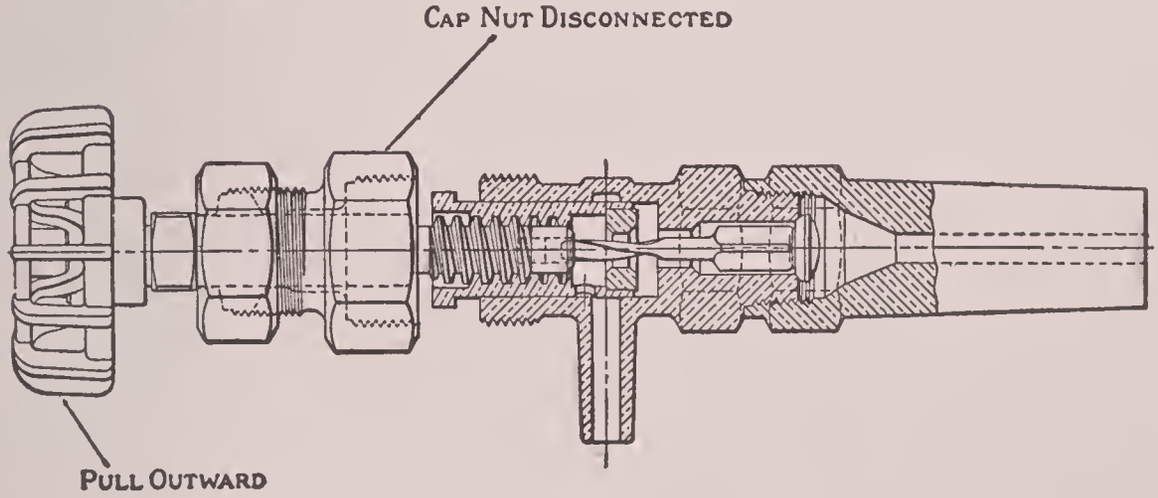


Fig. 17.

The body should be unscrewed from the spud in boiler occasionally, to examine and clean any accumulation of scale or sediment that may form in the outlet.

The spiral check requires but little, if any, attention, as it is continually off its seat and is not subjected to any wear.

When the stem is removed from the gauge cock it is good practice to put a few drops of oil where it works in the threads and packing.

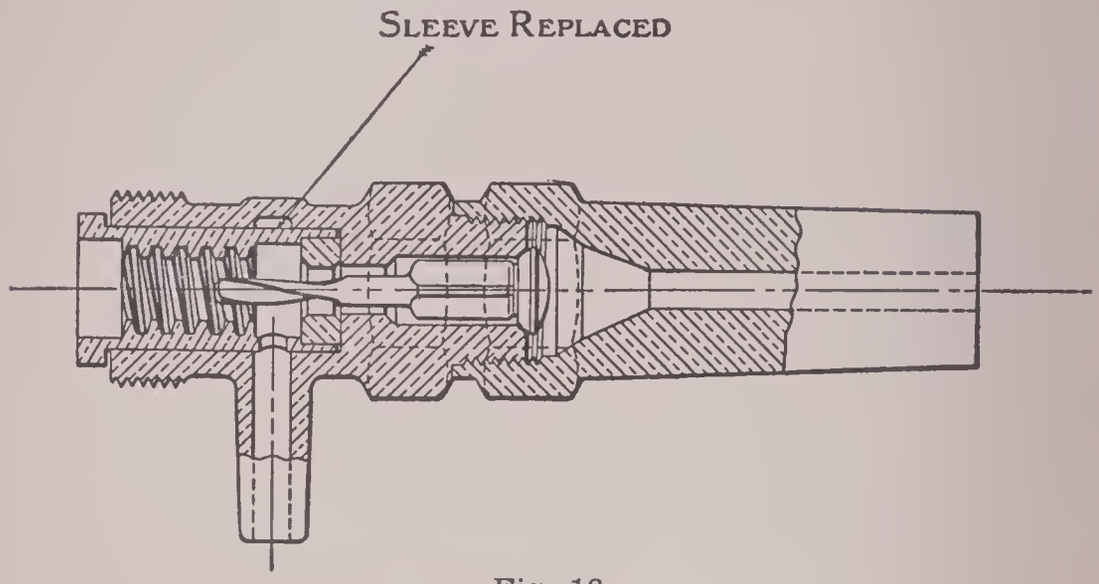


Fig. 18.

Fig. 15 shows the service position with the try-valve stem closed and the spiral check valve off its seat.

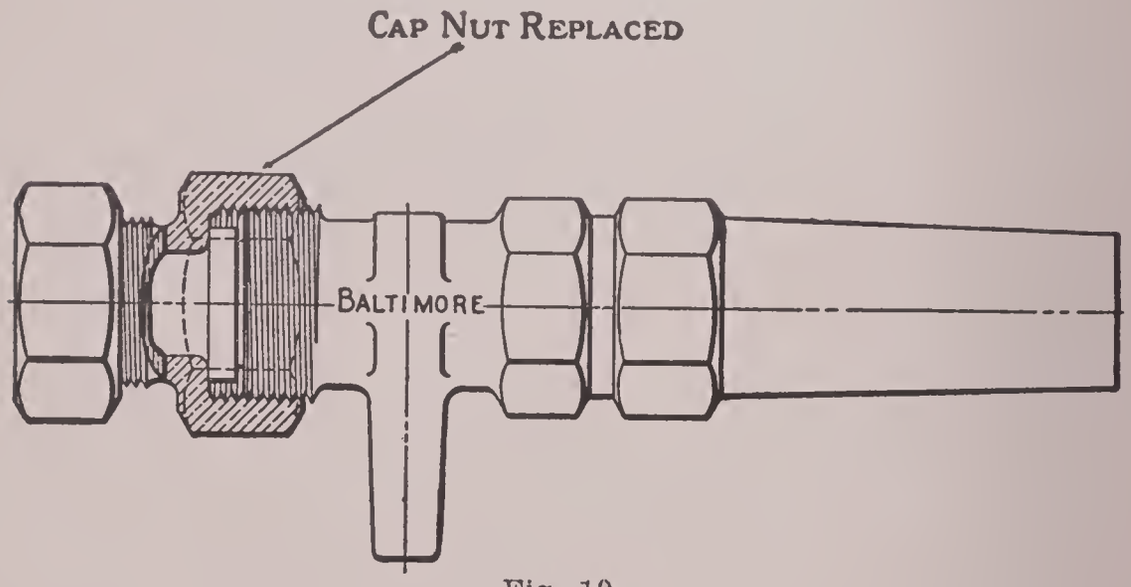


Fig. 19.

The spiral check valve is shown seated in Fig. 16, which is done by unscrewing the try-valve stem, shutting off the boiler pressure when necessary for repairs or renewal of seat.

The cap nut unscrewed and free from the body is shown in Fig. 17. This permits of the sleeve and the reversible valve seat being removed by pulling outward on the wheel of the try-valve stem.

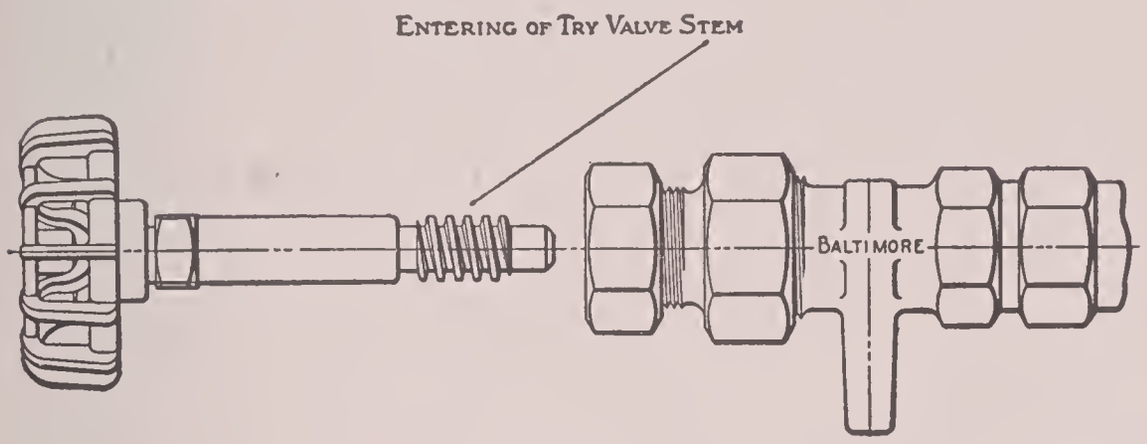


Fig. 20.

Fig. 18 shows the sleeve replaced in the body after the double seat has been reversed or renewed.

The cap nut is shown replaced in Fig. 19, screwed up tightly against the sleeve on the body.

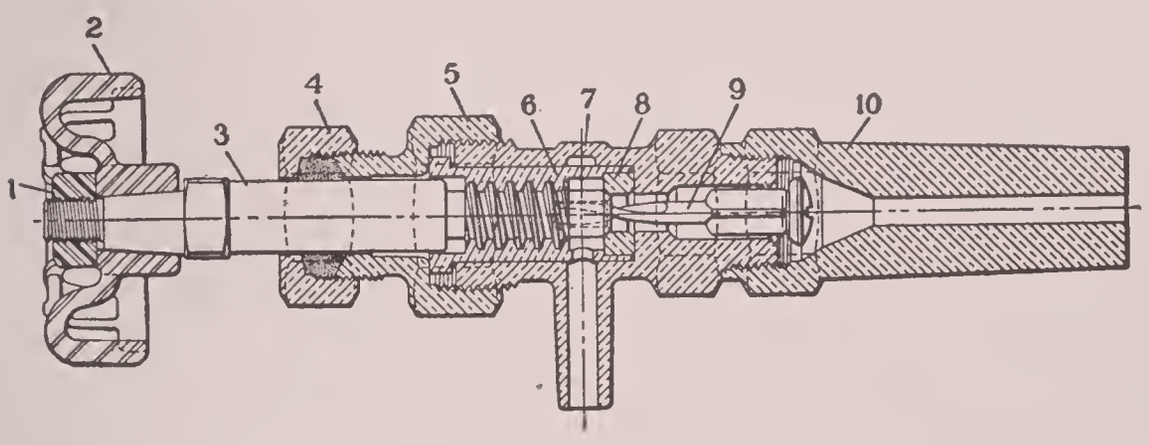


Fig. 21.

Fig. 20 shows the try-valve stem ready to enter in cap nut and sleeve to be screwed into the seat. The try-valve stem should be the last part to replace after repairs have been made, and under no circumstances should the try-valve stem and nut be screwed onto the body and into the sleeve simultaneously.

The sleeve, cap nut and try-valve stem should be applied separately in the order named; care being taken to tighten the cap nut firmly on to the body before the try-valve stem is inserted.

Figure 21 shows the different parts of this gauge cock.

1 Nut	6 Sleeve
2 Zero Wheel	7 Double Seat
3 Try-valve Stem	8 Body
4 Packing Nut	9 Spiral Check Valve
5 Cap nut	10 Spud

The operating wheel is fastened to the stem in such a manner that it will not work loose. It is made of malleable iron and is designed and constructed so as to be cool and easily handled.

2. Proper Register of Steam Gauge.—"How can you tell if the steam gauge is registering properly?"

Answer.—By comparing it with the test gauge or with the pop valve when it opens; also by the working of the engine, the sound of the exhaust and the whistle; the steam escaping from the open gauge cock, or the pressure shown on the air gauge. If the air-pump cylinders are same size, steam and air end, you can not get more air than you had steam, but would get less the amount of friction of piston in air pump and weight of same. If your steam gauge was fast, or indicated more pressure than you had on the boiler, you would notice it by the engine not handling her train properly. If the gauge was slow and did not show as much steam as was being carried on the boiler, and pop valves did not open at the maximum pressure, the engine would be more slippery.

3. STEAM GAUGE WITH TWO POINTERS.—"We have some locomotives equipped with the Crosby steam gauge which has two hands or pointers. What is the object of the larger one?"

Answer.—These gauges have an opening in the dial for the large figures so that the longer pointer may be in a vertical position on the dial and the figures shown through the opening denote the pressure which the boiler is permitted to carry in service, expressed distinctly and without reference to the other figures on the dial. The pressure is always easier determined by the position of the long pointer. The dial also has a circle of small figures denoting the pressures to which the gauge is adjusted, the same as on an ordinary dial. The large and small figures have respectively a large and small index; one is a check upon the other, as each should always indicate the same pressure, and the large figures shown at the top and the long index make it a very desirable feature, especially at night.

AUTOMATIC BELL RINGERS AND THEIR TROUBLES.

Question 1. Should a bell ringer refuse to work, what should be done?

Answer. Failure of this mechanism is due as a rule to neglect of the engineer or fireman. Regardless of whether compressed air or steam is used, oil for lubricating the cylinder is needed and the trouble is usually not an insufficient quantity of oil, but too much is used. The result is the exhaust pipe becomes filled with cooked oil and dirt and thus the pressure cannot escape as the bell pushes the piston down. A bell ringer failing to work should therefore be taken apart to see that it is clean.

Stoppage may result from a leakage of the piston packing ring, but this comes on slowly and is indicated by a gradual weakening of the action so it is not difficult in this case to locate the trouble.

The mechanism being simple, when it refuses to work the cylinder-head should be taken off and the parts removed.

THE GOLLMAR BELL RINGER.

This bell ringer is arranged so as to automatically start the bell ringing when the locomotive whistle is sounded. This is shown in Fig. 1. A small chain is connected to the whistle which automatically opens a small valve in the cab, which admits steam or air pressure to the bell ringer. This valve is close to the engineer's

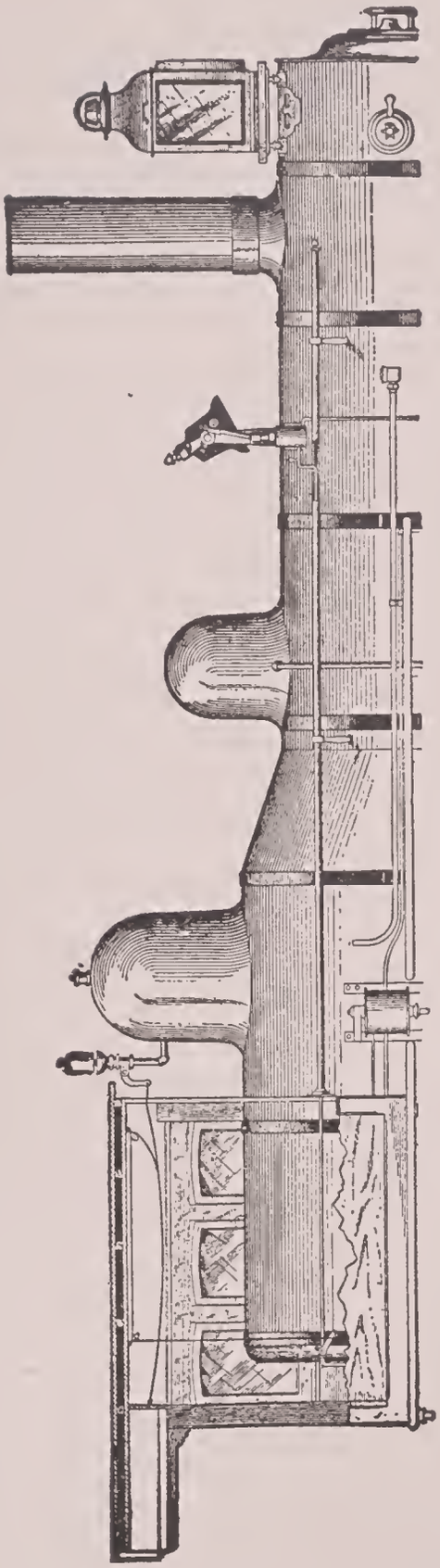


Fig. 1. Shows Whistle Connection and Application of Gollmar Bell Ringer.

hand, and may readily be opened without pulling the whistle cord.

While steam pressure may be used to operate this and other bell ringers, air pressure is much preferable, especially in cold climates.

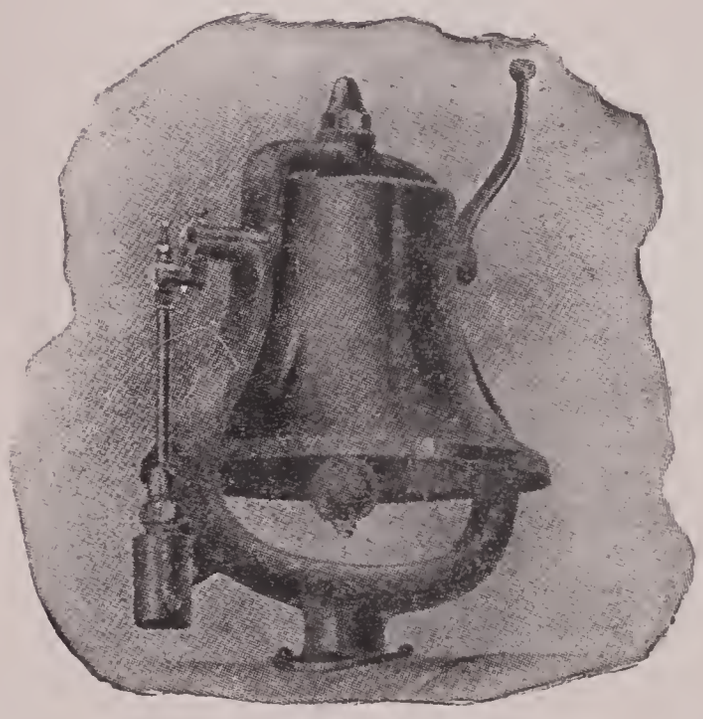


Fig. 2. View of Bell Ringer.

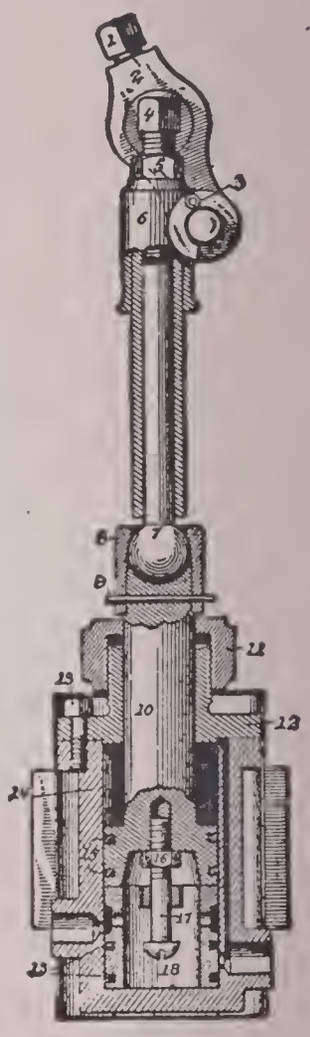


Fig. 3 Gollmar Bell Ringer. (Sectional View.)

The construction and its action are as follows—(See Fig. 3). There are two openings near the bottom for pipes; the upper one is the inlet, the lower is the exhaust. Pressure is admitted through the upper opening, opposite an annular groove in valve 18, through which four holes are drilled, admitting the pressure under the

single acting piston 10; this causes piston 10 to rise, forcing the bell to swing. Piston 10 has a stroke of one and one-fourth inches when at its extreme travel; crank 2 has a stroke of four inches. The connecting rod is in two sections, 6 and 7, which allows the crank 2 to make a complete revolution without causing piston 10 to move. When the ringer is started to work the piston 10 will be driven upward, causing the bell to swing, and valve stem 17 will raise valve 18, closing inlet port, and use pressure expansively by traveling the length of the lap before the lower edge of valve 18 will open the exhaust port. The bell, having received an impulse, will continue its motion after the piston 10 has reached the upper end of its stroke, the crank box 6 sliding on rod 7. The impetus which the bell receives being expended, it will fall, the set bolt 4 will strike the end of rod 7, and piston 10 will be forced downward (being open to the exhaust below) coming in direct contact with valve 18, thereby closing exhaust port and opening inlet port after cushioning on the pressure remaining under piston 10 subsequent to the closing of the exhaust on account of the exhaust port being placed slightly above the bottom of the cylinder. It will be seen that valve 18 is only operated at the terminations of the piston 10 stroke. Packing rings 15 on the piston and on the main valve are packing rings standard to the Westinghouse eight-inch air pump reversing valve. As the rings are kept in stock by all railroads using air-brakes, no extra supply need be carried by them.

The bell ringer can be easily adjusted to use pressure in proportion to the power required. This is accomplished by means of valve stem 17, which is secured in its adjusted position by jam nut 16. No change in

length of connecting rod is required in making this adjustment. These bell ringers have been used successfully when cutting off pressure after the piston has moved but three-eighths of an inch of its stroke. This arrangement makes it so economical in use of pressure that air is always used in preference to steam, and it has never caused any trouble with train brakes.

This little machine has no outward moving parts except the rod. Its valve is attached to the piston.

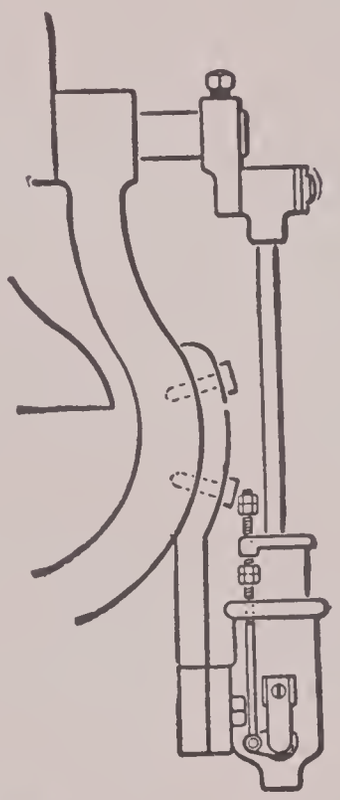


Fig. 4. Sansom Bell Ringer.

THE SANSOM BELL RINGER.

The Sansom bell ringer is operated by the admission of compressed air pressure under the piston, which forces piston upward and carries a connecting rod attached to a crank on the bell shaft, as shown in Fig. 4. When an arm, extending on the left of the piston, has

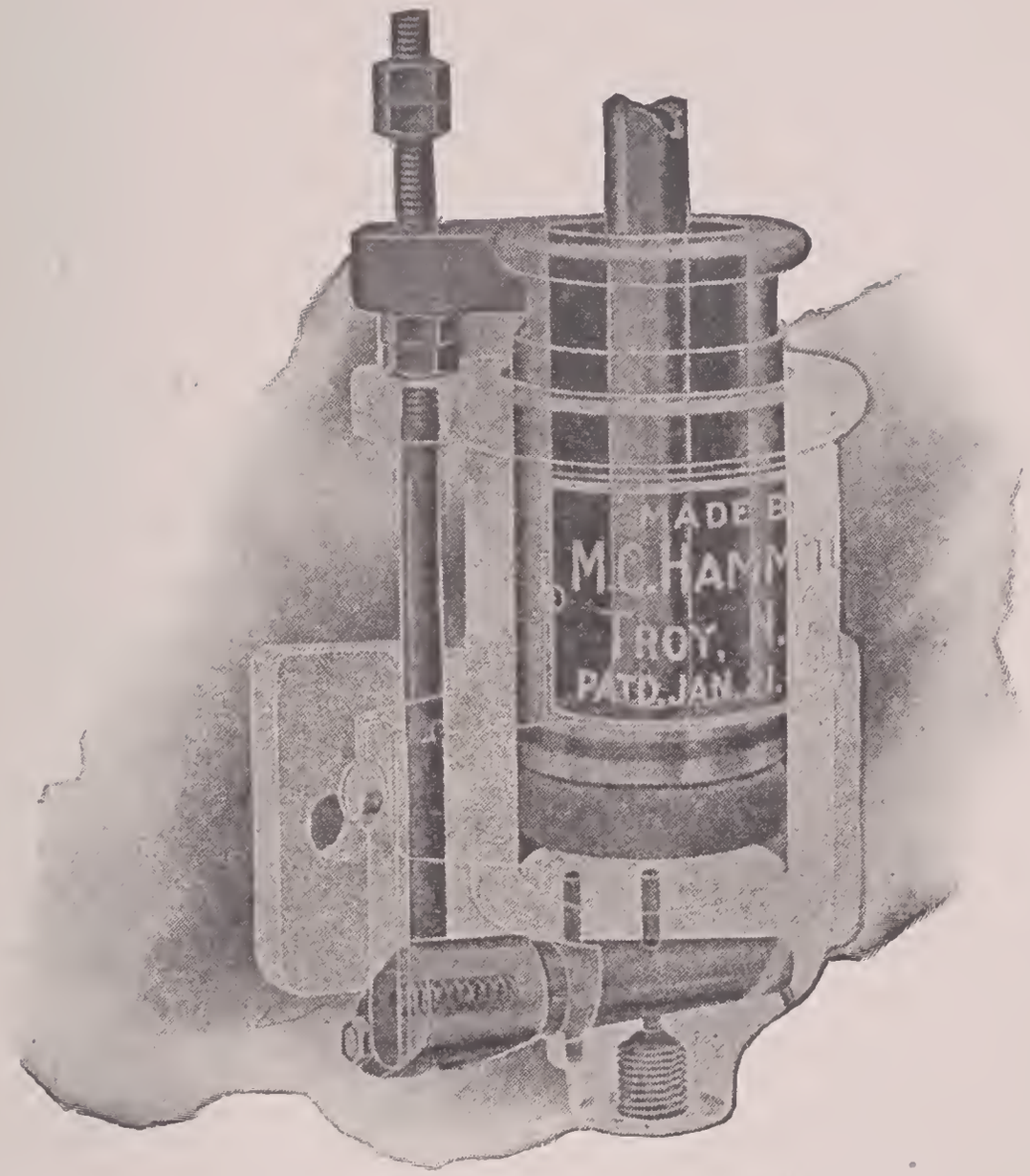


Fig. 5. Sansom Bell Ringer, Showing Interior Mechanism.

traveled to the upper set of lock nuts on reversing rod, the admission port begins to close and the exhaust port to open, thus allowing the air to escape from the cylinder and the weight of bell to force piston to bottom of cylinder.

STEAM HEATING SYSTEM.

1. Steam Heat Reducing Valve.—"How does the steam heat reducing valve control the pressure?"

Answer.—Similarly in manner to the operation of the air-pump governor. The valve controlling the opening in the regulating or reducing valve is forced from its seat and held in open position by the pressure put on it by a spring above the diaphragm. The more tension put on the spring the higher the pressure will be in the trainline before closing. When the steam pressure on the other side of the diaphragm exceeds the strength of the spring it is forced upward, thus preventing further flow of steam from the boiler to the heating system until the pressure is reduced. Ascertain the kind of valve used on the line where you are employed, and if you are unable to get one to take apart so you can trace the steam through it, write to the manufacturers for a descriptive circular, which will be gladly furnished. They want you to know how to handle their appliances and always grant requests for information.

2. Steam Heat Valve Inoperative.—"In the event of the steam heat reducing valve being out of order, how would you heat the train until repairs could be made?"

Answer.—If you have a Mason regulating valve and it becomes inoperative, the cause is probably dirt or grit around the piston D in or above the dash pot. For quick repair remove the dash pot and clean the piston, replacing same. Then if steam does not get to train

pipe after this treatment, take out the piston and place a small block in it of sufficient thickness to raise the steam valve from its seat when the dash pot casing is screwed into place. This will raise the steam valve from its seat and allow the steam to flow directly through the valve to the train pipe. Of course, when the valve is removed the pressure must be regulated by the globe valve next to the boiler attachment. If the engine is equipped with a Gold pressure regulating valve and it should fail to allow steam to go through into the train pipe, take out the bottom plug or cap, remove the spring and valve and steam will flow through the regulator the same as it did with the Mason valve. In each of the above types of valve it would be proper to relax the tension of the regulating valve spring. If the valves are kept clean they will give very little trouble. Do not pound the side of a regulating valve, as it often springs the case and prevents proper operation and repair. You have failed to mention the kind of valve that gave you the trouble, but in any case make repair quickly if you can, and if unable to repair get the valve out and the steam back into the train. Keep the cars comfortable and get in on time. Report the valve for repairs at the terminal.

Allowing the train to get cold, sometimes makes the passengers "hot," and frozen pipes are expensive.

3. Cars Not Properly Heated, While Gauge Shows Required Pressure.—"If the steam gauge showed the required pressure and the cars were not being heated properly, how would you proceed to locate the trouble?"

Answer.—Close the shut-off valve on train line and uncouple steam heat hose between engine and train, then open the shut-off valve and pressure regulating valve,

and in this manner determine that the steam was being furnished back of the engine. Would then couple up steam heat hose and open all valves through to rear end of train. This will show that the steam is or is not obstructed in the main steam heat pipe. Next close valve on rear end of last car, but not tightly, leaving it open sufficiently to take care of the condensation. Then open all valves to radiators in the coaches and the drip valves to let out the condensed steam or water, thereby getting a circulation through the heating pipes or coils. If this will not heat the cars the chances are that there is not radiation enough in the pipes to raise the temperature. It's not the pressure shown on the gauge on the engine that keeps the cars comfortable, but the circulation of the steam in the pipes, and when cars are not provided with automatic drips, trainmen sometimes allow the pipes to fill with water and the cars get cold. When the engine piping is under the tender there is little or no trouble with it, but if it is on top of tender there is danger of the tender being flushed at water stations, or an accumulation of snow melting and surrounding the pipe with water which will condense the steam very rapidly. Keep the back of the tank clean and the steam pipe dry.

LOCOMOTIVE BOILERS.

1. Form of Locomotive Boiler.—"Describe the general form of locomotive boiler."

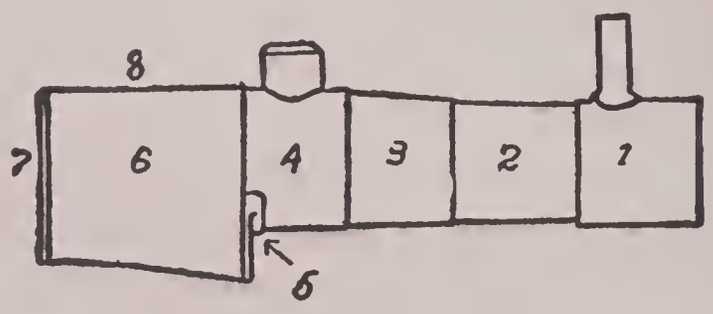
Answer.—A locomotive boiler is cylindrical in form, with a smokebox at one end and a firebox at the other. The firebox consists of a flue-sheet, side sheets, crown sheet and back sheet. The side sheets, flue and back sheets are secured to the boiler shell by a mud ring and stay-bolts. The crown sheet is supported by crown bars or radial stays. Flues or tubes run through this cylindrical part and are secured to the front and back flue sheets. These parts are surrounded by water from which steam is generated. Boilers are provided with steam domes to insure dry steam being used as much as possible, and also to provide a place for throttle valve, pop valves, whistle, etc. There are several kinds of locomotive boilers; the straight boiler, Bellpaire, wagon-top, extended wagon-top and wide firebox types.

2. Wagon-Top Boiler.—"Describe a wagon-top boiler."

Answer.—A wagon-top boiler has a shell over the crown sheet much larger than the cylindrical part of the boiler, with the dome located over the firebox and crown sheet supported by crown bars. The large part tapers off to the boiler shell ahead of the throat sheet. An extended wagon-top boiler has the high part or wagon-top extended farther forward, usually to the first ring of the boiler shell, and the dome is placed ahead of the crown sheet. The extended wagon-top type gives increased steam space in the boiler.

3. Boiler Sheets.—"Will you kindly illustrate the outside sheets of a boiler and show which sheet is called the throat sheet?"

Answer.—In the illustration herewith, 1 represents the smokebox and extension front; 2 the first ring of the boiler; 3 the second ring, or slope sheet if on an incline forming a wagon top; 4 is the third ring or dome sheet. These parts form the barrel of the boiler. Sheet 5 is the sheet that connects the underside of the barrel of the boiler to the outside shell of the firebox and is usually termed the throat sheet; 6 is the outside sheet of the firebox; 7 is the back boiler sheet, or head; and 8 is the roof sheet.



The firebox consists of a back sheet, flue sheet, two side sheets and a crown sheet. The front flue sheet is next to the smokebox. The lower edges of the inside and outside shells of the firebox are riveted to an iron ring called the "mud ring."

4. Heating Surface of a Boiler.—"Will you please publish the rule showing how to find the square inches or feet of a firebox and door and the flues of a locomotive?"

Answer.—We presume you mean the heating surface of a boiler. This is intended to include the surfaces in the boiler and firebox that are exposed to the heat of the fire and generated gases on one side and have water on the other. The total heating surface in a locomo-

tive boiler is the crown sheet, side sheets, flue sheet and back or door sheet. The area of the front flue sheet is usually neglected in figuring the heating surface. Multiply the length of the sides and ends of the firebox by the height in inches and multiply the length of the crown sheet by its width in inches. Add the product together and subtract the combined area of the fire-door and the area of the flues in the flue sheet and divide by 144, which will give the area in square feet of direct heating surface of the firebox. The heating surface of the flues is called the "indirect" heating surface. Multiply the circumference of one tube in inches by its length in inches and multiply that product by the total number of flues, and divide the product by 144, which will give you the heating surface in square feet of the flues. This, added to the heating surface of the firebox, will give the total heating surface. A flue 2 inches in diameter will have a circumference of 2 multiplied by 3.1416 equals 6.2832 inches. If 16 feet long, 16 feet equals 192 inches. Then 6.2832 multiplied by 192 equals 1,206.3744 square inches, the heating surface of one flue. Now multiply this by the number of flues and divide by 144 and you have the square feet of heating surface of flues. Always figure the outside diameter of flues, as that is the area that is exposed to the water, and it should be assumed that the grate is on the level with the bottom of the firebox. If the grate is above the lower edge of the firebox this height should be deducted from the heating surface.

5. How would you take care of a boiler with leaky tubes or fire-box?

Answer.—If the flues or the fire-box are leaking sufficiently to put out the fire at any point in the fire-box, a good sized bank should be kept at that point so as to keep

the cold air away from the leak. The firing should be done as carefully as possible, and in many instances if the firing is done carefully the leakage will take up and entirely stop during the trip. If necessary to clean the fire on such an engine, throw a few sticks of wood upon the arch or next to the flue sheet so as to blaze up and keep the cold air from the flues. When the engine finishes the run, with dampers closed, let the fire die down entirely in the box before knocking it (covering the stack also helps). Fire up the engine with a good slow wood fire and without the use of the blower. A good wood fire will often stop leaks of flues and fire-box on the road.

6. Carrying Water in Boiler.—"Why is it bad practice to carry water too high in a boiler?"

Answer.—Wet steam is less effective than dry steam. When the water is too high in the boiler it is carried into the dry pipe and to the valves and cylinders when throttle is open. More water is used, more fuel consumed and the efficiency of the engine is decreased. The wet steam or water carried over into the steam chests and cylinders destroys the lubrication and increases the friction on the valves and cylinders. Keep your crown sheet wet, but use steam as dry as possible to make time or pull tonnage always.

7. Circulation of Water in Boiler.—"What is meant by the circulation of water in a boiler?"

Answer.—A free movement of the water so that it may come in contact with the heating surface, and after being converted into steam be immediately replaced by a fresh supply. Proper circulation of the water is essential to the efficient operation of a boiler, as it tends to keep all its parts at a nearly uniform temperature and prevents overheating, as is the case when the boiler is

filled with mud or scale. The mud does not circulate and can not carry away the heat and the sheets are burned. When a boiler is filled with cold water the water is dense, and there is little, if any, circulation, but as soon as a fire is built in the firebox or furnace the sheets become heated and the heat is immediately absorbed by the water coming in contact with them. As the water rises in temperature it becomes lighter and rises to the surface, and the cooler water, being heavier, flows down in the space, between the flues and boiler shell, promoting the circulation. The rapidity with which heat may be absorbed from the heating surface depends on the effectiveness of the circulation in the boiler. A poor circulation will result in a poor steamer.

8. Water Splitting in a Boiler.—"What caused this? Several years ago I was firing one of the old Roger engines on the P., F. W. & C. We were running down a slight grade, using some steam, lever in second notch from center. Engineer was pumping her up, getting ready for the big hill ahead of us. We had three gauge cocks, but no water glass. On trying the lower cock he found dry steam, and, without closing it, he opened the upper gauge cock and found solid water. He called my attention to it, and while we were talking the conditions were reversed, viz., water at the lower, and dry steam at the upper cock. Neither of us had ever heard of such a thing before. It changed three times while we were looking at it. Then he closed them and nothing happened. We tried it repeatedly afterwards at same place, but never saw it again. The boiler had been washed out only a couple of days before and we had good water. Please explain."

Answer.—This might come under the head of what is

termed "water splitting in a boiler." The writer has heard of water being so light in some instances that the steam would get under it and hold it in suspension, but it is only in rare cases. There is no better way to determine the water level in a boiler than with the ordinary gauge cock with a free opening to the inside of the boiler, although sometimes they are located behind a crowfoot or a brace that interferes with their proper working. If such was the case and a hole drilled through the brace in the boiler, it might become stopped up opposite the gauge cock and the steam would leak down between the boiler head and the brace on the inside, which would perhaps cause a flutter of steam and water to show at the gauge cock when open. In a bad-water locality, on account of bubbles in the water, we might get a condition of this kind occasionally, but where good water is used we are unable to explain it. If we could give you a good, clear explanation of this case it would be difficult to determine at any time if the crown sheet was scorched on account of low water.

9. Priming and Foaming.—"What is the difference between priming and foaming in a boiler?"

Answer.—Priming is caused by filling the boiler too full of water (think of priming a pump). Foaming is caused by the impurities of the water or by foreign substances, such as oil, soap, or anything that will cause water to foam.

10. Test for Low Water.—"Kindly answer if the test for low water is safe, when water comes in water glass if you close top water cock, bottom one remaining open. Explain fully why we close top cock and how we can know how much water is in boiler when out of sight in the glass and can not be found in gauge cocks.

Also say if there is any safe way of knowing when water is too low?"

Answer.—Much depends on the distance the bottom water glass is above the highest point of the crown sheet. Would not recommend it as safe practice to let your water get so low as to require this method of ascertaining its level in the boiler. If you can not get water when you have one or two gauges you have no assurance that you will be able to get it after it is out of sight in the glass, and it is better practice to work the engine so you can maintain maximum boiler pressure and water level than to trade water for steam and get the worst of the bargain. Engineers sometimes get into trouble taking chances on low water, and safety is the first consideration, always. (Don't do it.) There is no safe way of knowing where the water is if you can not determine the level by the gauge cock or water glass. The reason that water shows in the glass when top cock is closed is, because at the time the top cock is closed the glass is full of steam at a temperature corresponding to the pressure in the boiler. Closing the cock shuts off communication with the boiler at the top end of the glass, and the pressure of the steam in the boiler will force water into the bottom water glass cock providing the water is above the opening; the steam in the water glass is condensing, due to its exposure to a lower temperature, and the water is forced up into the glass.

11. Filling Boiler of Dead Engine.—"How would you fill a boiler if a live engine was near at hand and plenty of water was in tender of dead engine?"

Answer.—If the engine was equipped with a pump the proper thing to do would be to tow the dead engine up and down the track until the water was pumped into the

boiler. If the engine had no pump, would either get her to a hose connection with water tank or city pressure and fill the boiler through the blow-off pipe on the dome, or if you could get the live engine on an adjacent track, so that the branch pipe could be disconnected from the check on dead engine and the branch pipe from live engine be coupled up to check of the dead one, working the injector would fill the boiler of the dead engine.

Having heard how to fill the boiler of a dead engine by towing her, we took a 21x26-inch piston-valve engine and a 17x24-inch side-valve engine and plugged up cylinder cocks, relief or air valves, overflow pipes to injectors and the whistle valve, then opened injector throttle and engine throttle and placed the lever in direction that engine was moving, but with the tanks full of water we could not obtain sufficient vacuum to pull the water from the tender through the feed, injector, and branch pipes to the boiler, therefore, could not recommend even giving it a trial. Better get ready to be towed to a terminal than to waste time on theories, unless you know they will work out a successful termination of your difficulty.

When experimenting with these two engines, on account of the speed limit in the yard, we could not make more than eight or ten miles per hour, which was the possible cause of failure to fill the boiler. Boilers have been filled in this manner when a speed of from twelve to twenty-five miles per hour was attainable in distances of from six to ten miles. The delays to traffic, trains and engines crews, and the expense incurred, would more than offset the advantage unless it was an isolated case.

12. Troublesome Boiler Checks.—"I am firing an eight-wheel wagon-top boiler engine equipped with

No. 8 Monitor injectors on both sides. The boiler checks are in the barrel of the boiler and set about level with the center of same. The injectors are on a level with the top of the tank and they work in good shape until the tank is one-half empty and less. Then every time the injector on either side is shut off the boiler checks stick up, and they give no trouble at any other time when the tank is over half full of water. Both checks have been ground in, examined and pronounced all right and give no sign of leaking when injectors are not in use. What is the trouble?"

Answer.—From the description given of the action of the checks, it is the opinion of experts that the trouble is from sediment deposited on the valve and interior of the cage and passage to boiler through check, and that the check valve may be fitted too close to allow any deposit without interfering with the free action of the check. The height of water in the tank would in no way influence the boiler check if in proper condition, possibly the valve and seat may be battered sufficiently to cause too tight a fit for free action of the valve. This case would require a personal examination in order to render a definite conclusion, and we would recommend that the check be made sufficiently loose so that the valve would find its seat readily at all times when the injector was shut off.

Broken-off Check Valve.—"Can a broken-off check valve be repaired and engine brought in under steam? Explain in detail."

Answer.—That depends on the style of check valve used and its position in line with the highest point of crown sheet. With a check valve that had a check inside of the boiler shell, it would be easy, but with the or-

dinary check, screwed or flanged to boiler, it would be more difficult. However, if you could keep water enough on the crown sheet to fire up with, or fill the boiler from a hose or water supply, or by being towed after plugging the check, or if flanged the check could be removed and a blind gasket inserted between the check and the boiler, you might be able to accomplish results when check valve was broken off an engine. But usually in a case of this kind the engine is damaged to such an extent that it would not always be advisable to consume the time necessary to put her in shape to bring her in under her own steam. If the line is busy, get the engine towed to the shops and have the repairs made without delaying other trains.

13. Part of Boiler under Greatest Pressure. —"What part of a locomotive boiler has the greatest pressure?"

Answer.—The bottom part; steam is expansive and exerts the pressure evenly in all directions; the bottom part, having to support the weight of the water as well as the steam, has the greatest pressure.

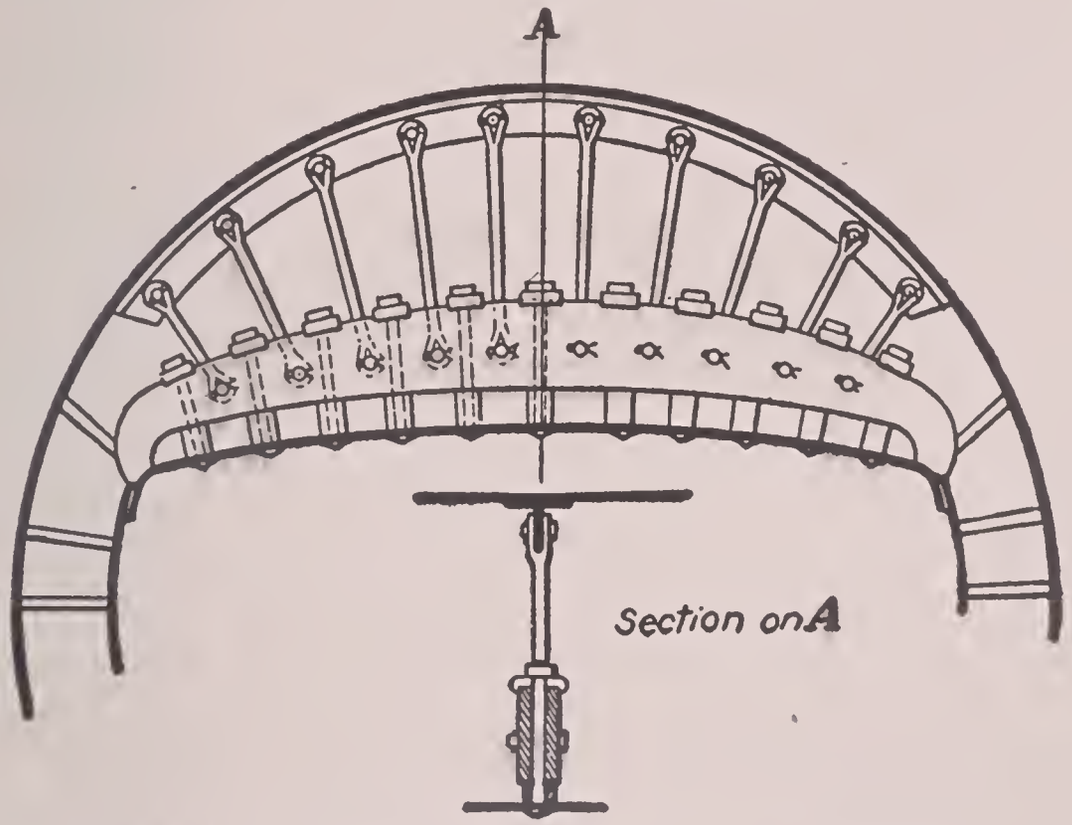
14. Mud in Leg of Firebox.—"What would be the effect if the leg of the firebox became filled with mud?"

Answer.—The water would not come in contact with the inside sheet and it would become burned or overheated. Heat would cause it to bulge and crack and the staybolts would pull through the sheet, necessitating patches or half side sheets on the firebox.

15. Sling-stayed Boiler.—"What is meant by a sling-stayed boiler?"

Answer.—A boiler that is built with crown bars, as shown in sketch. Note that the ends of the crown bars rest on the side sheets, and that the bars are also sup-

ported between the ends by sling stays that are fastened to the crown bars and dome, or roof sheet of the boiler, which in turn hold the crown bolts that pass through the crown sheet and are riveted over. This is a sling-stay and crown-bar boiler. If the bolts were severed and riveted into the crown sheet and dome sheet it would not be necessary to use the crown bar, and the boiler would then be called a radial-stayed boiler.



Sling-stay and Crown-bar Boiler. Illustrating Question No. 15.

16. Radial Stayed Crown Sheets.—"What are the advantages of radial-stay crown sheets?"

Answer.—When crown bars are used to support crown sheet, the crown sheet is made more flat than with radial stays, and the crown bars take up water space, and where muddy water is used, help to collect mud on the crown sheet. When radial stays are used the crown sheet may be given considerable curvature and the stays

placed as near right angles as possible. The advantage is that less mud will accumulate on the crown sheet with radial stays than with crown bars, as the wash of the water from the curved surface washes the mud from the crown sheet. Radial stays take up less room and they are much cheaper, give better chance to wash out boiler and are more favorable for inspection.

17. Course of Steam from Boiler to Stack.—"If steam comes, or exhausts, through the cylinder saddle it certainly has to go through the cylinder saddle before doing its work. A blue print I have says, 'Steam passes

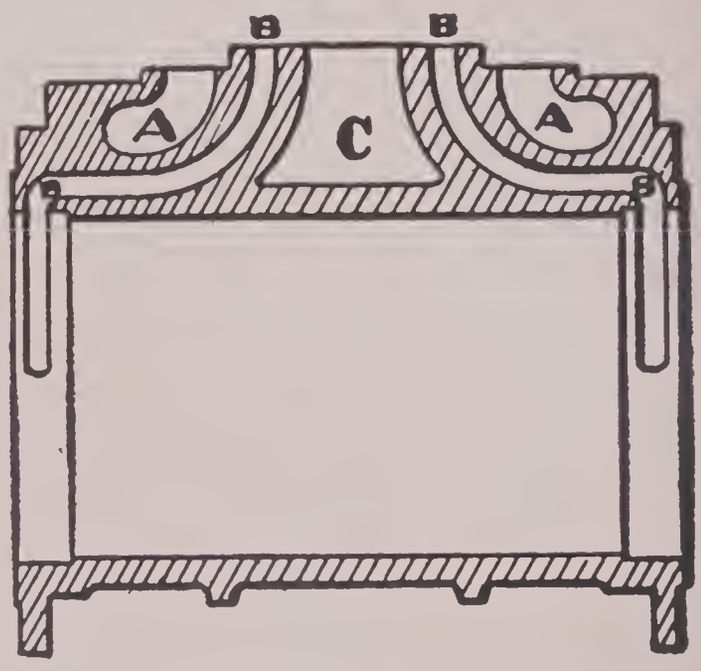


Fig. 1. Longitudinal Section of Cylinder.

through the throttle, stand pipe, dry pipe, steam pipe, cylinder, saddle, and admission ports to the cylinder.' The answer to examination question reads: 'Steam passes through the dome, by the throttle valve, through the dry pipe and steam pipes, and into the steam chest.' Why not say, 'Steam pipes, cylinders, saddle, steam chest, and admission ports,' or vice versa, 'thence to the cylinder.?'

"How many openings in cylinder saddle? Name and give use of each."

Answer.—The answer to a question does not always give every detail sufficiently clear to a student to enable him to understand it without further effort or study on his part. We will try to explain this more fully, and would suggest that you examine a locomotive that is in the shop for repairs, with flues out of boiler and covers of steam chests and cylinder heads removed.

Steam is generated at or near the heating surfaces of the boiler and rises into the dome. When the throttle valve is open steam enters the stand pipe, and follows through it, to the dry pipe to the "nigger head," or tee, in the smokebox. It then enters the steam pipes and is conducted to the cylinder saddle, thence through the passage *A A* (see illustration) to the steam chest. If the valve is now in the center of its seat it can go no farther, but when the port is uncovered by the valve, steam is admitted to the end of the cylinder nearest the opened admission port, shown as *B B*, and exerts a pressure on the piston nearly equal to that of the steam chest pressure while the port is open. This pressure is exerted on the piston and transmitted to the piston rod and connecting rod to the crank pin, and produces a rotative effect on the wheel in proportion to the pressure and the position of the crank pin above or below a line drawn through the center of the main driving axle and cylinder. If the steam is cut off before the piston has reached the end of its stroke, the valve having closed the port, the steam confined in the cylinder forces the piston to the completion of its stroke by its expansive force acting like a spring. This is the expansion of the steam in the cylinder. When it has pushed the piston

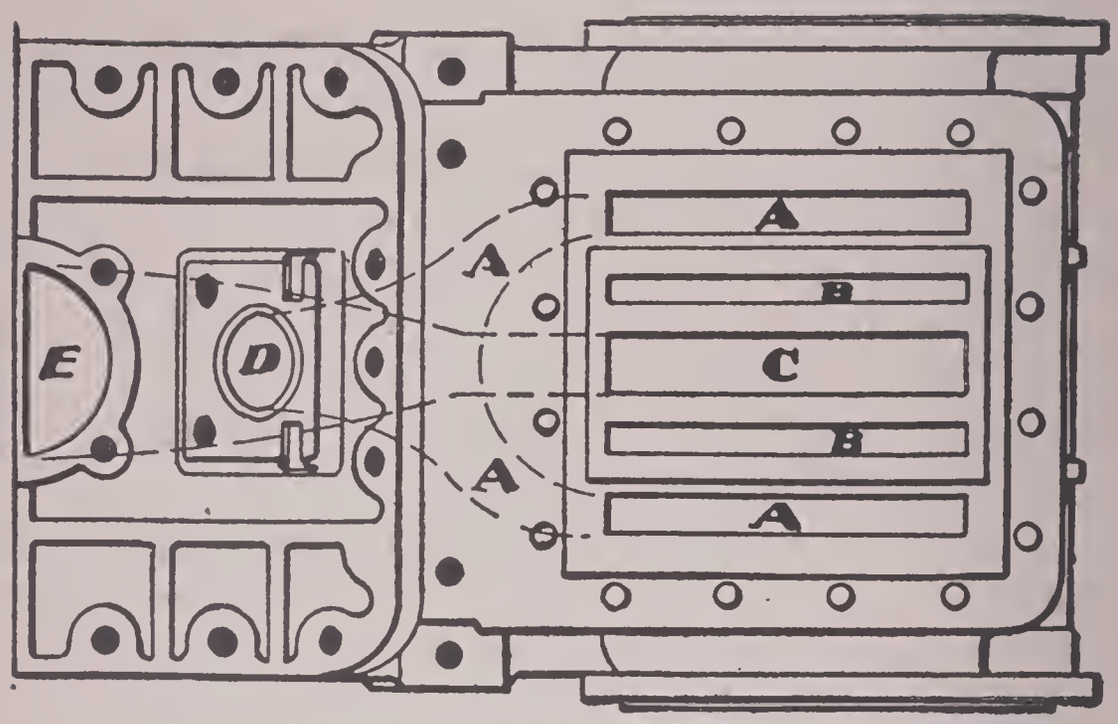


Fig. 2. Valve Seat and Cylinder Saddle, Top View.

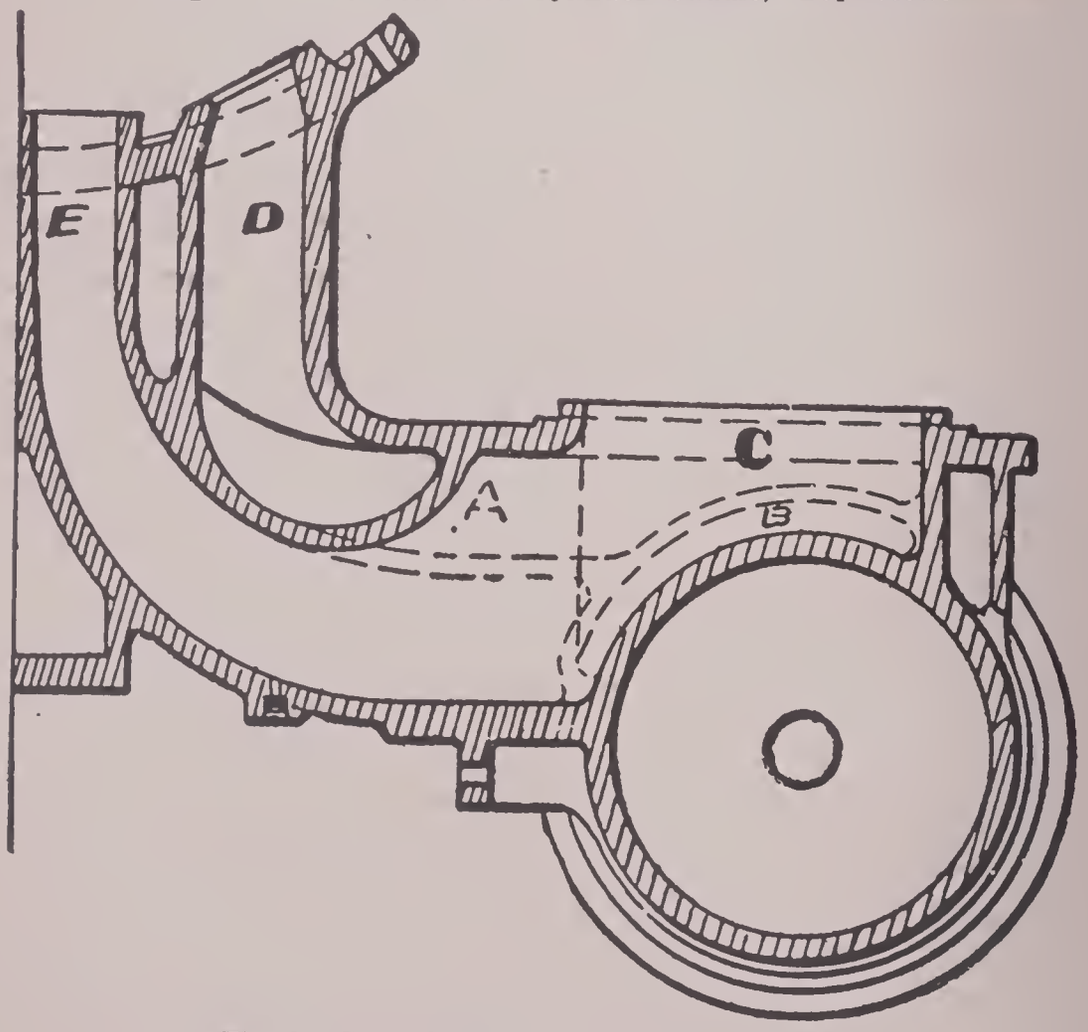


Fig. 3. Cross-Section of Cylinder and Saddle.

to the end of its stroke, it escapes through the admission port which it entered, passes under the valve, over the bridge, and into the exhaust passage *C*, through the cylinder saddle again, into the exhaust pipe and out through the nozzle tip, through the petticoat or draft pipe and out of the stack.

There are usually five openings in the cylinder saddle to the steam chest, as shown in the illustrations. Fig. 1 shows a sectional view if the cylinder was cut in two and lengthwise through its center. Fig. 2 is a view looking down on the valve seat and cylinder saddle. Fig. 3 is an end view showing its construction, and the dotted lines represent lines that can not be seen. Ports *A A* are to admit steam to the steam chest when the throttle is open. Ports *B B* admit steam to the cylinders alternately when they are uncovered by the valve. Ports *B B* and *C* exhaust the steam from the cylinder when the exhaust cavity of the valve extends over the bridge between ports *B* and *C*. Opening *D* in the cylinder saddle is to connect with the steam pipes to the steam passage for the purpose of supplying steam to the steam chest, and opening *E* is to allow the steam to escape from the cylinders through ports *B* and *C* to the exhaust.

18. HEATING SURFACES. "We have an engine here in heavy transfer work that has given a great deal of trouble to the fireman about steaming; here are her dimensions: Weight 160,500 pounds, tractive force 36,400 (no engine trucks), heating surface 1,905 square feet, grate area 29 square feet, cylinders 22x28 inches, drivers 57 inches in diameter, steam pressure 180 pounds.

She has a 5-inch nozzle and no petticoat pipe; is very hot at the door and the smoke does not fill the stack,

but strikes the right side. Is this enough heating surface for the cylinders?"

Answer. The heating surface of this boiler, in proportion to grate area, is 65½ square feet per square foot of grate area, and compares favorably with the average, as boilers of recent construction are designed with an average of 66 to 83 square feet of heating surface per square foot of grate area, this includes boilers with wide fire boxes. When designing a boiler, it is the custom to allow a certain amount of heating surface for each cubic foot of piston displacement. Experiments have determined that the number of square feet of heating surface should be from 320 to 415 times the piston displacement in cubic feet; ordinarily 385 square feet of heating surface per cubic foot of piston displacement is allowed, although much depends on the class of engine, the service she is designed for, wheel base, etc. In using the following formula: H equals heating surface, D equals diameter of piston in inches, and L equals length of stroke in inches, we have H equals $.175 \times D^2 \times L$, or 2,371 square feet of heating surface that should be allowed for this engine. It would appear that she was slightly over cylindered for the heating surface; also that the draft appliances are not properly adjusted to obtain the best results. The stack should be put in line with the exhaust nozzle so that the exhaust steam would fill the stack on all sides, and the diaphragm should be raised to get the draft through the upper flues, thereby reducing the temperature at the fire door for the fireman and utilizing the heating surface that you now have. If changing the diaphragm can not effect this, an extension on the nozzle top of about eight or ten inches that will bring the tip up to the center line of the boiler may give

better results. Do not get discouraged. Improvements in the boiler design is a subject that is interesting the mechanical men at present. Perhaps the cylinders will be bushed if she remains in service. Would say most of your trouble is in the front end, if flues are clean and cylinder packing and valves are in good condition.

19. Temperature of Sheets vs. Temperature of Water Against Them.—"Will the temperature of the sheets exceed the temperature of the water constantly against them? If so, how much?"

Answer. The temperature of steam or water in a boiler at 200 pounds pressure is 387.8° Fahrenheit, while the temperature of the firebox, when the engine is working, is from 2,500° to 3,500°. It is admitted that the water does not come in contact with the sheets at all times, but as the heat is absorbed by the water a thin layer of steam prevents the water from coming in contact with them at times, and the result is cracked and burned fire box sheets. The water does not carry the heat away fast enough and the sheets will not absorb it without damage, hence the reason for larger bridges in flue sheets, and wider water space around fire boxes on high-pressure engines.

20. Circulation in a Boiler.—"What is meant by circulation in a boiler?"

Answer. The free movement of the water so that it may come in contact with the heating surface, and after being converted into steam a fresh supply taking the place of that evaporated. As the water absorbs the heat it becomes lighter and rises to the surface, the cold water, being heavier, taking its place. The circulation depends on the condition of the boiler, which should be

free from scale or mud and the flues should be spaced to allow free movement of the water.

21. Temperatures of Steam at Different Pressures.—"What is the rule for figuring the temperature of steam in a locomotive boiler when it is at different pressures?"

Answer. There are several formulas or rules to determine the temperature of steam at various pressures, when a steam table, giving temperatures and pressures, is not available. One of these is given worked out below, and gives an error of less than 1½ degrees in nearly all cases for pressures of over 100 pounds.

t=temperature in degrees Fahr.

p=gauge pressure in pounds per square inch.

$$\text{then } t = 14 + \sqrt{p} + 198 \text{ minus } \frac{(p - 100)}{11}$$

Taking 200 pounds we have p=200.

The square root of 200 is 14.15; this multiplied by 14 =198.1, and 198.1 plus 198=396.1; pressure minus 100, divided by 11=9.1 (or 200 minus 100=100, which divided by 11=9.1); then 396.1 minus 9.1=387 degrees, the temperature of steam at 200 pounds pressure.

22. Temperature and Pounds Pressure.—"Will the temperature of steam be greater at 200 pounds than at 100 pounds pressure?"

Answer. The temperature of saturated steam, or steam that is in contact with the water from which it is generated, at atmospheric pressure is 212° Fahrenheit. At 100 pounds pressure per square inch the temperature is 337.8°, at 200 pounds pressure per square inch it is 387.8°. Steam in a locomotive boiler is saturated steam, and the temperature depends on the pressure.

23. Uptake of Boiler.—"What is meant by the uptake of a boiler?"

Answer. This applies to what is known as the area of uptake and funnel. In determining the size of funnel conditions must be considered, and this question refers to marine practice, rather than locomotive, and means the area of funnel to that of the grate and is determined by results based on best practice. The area is usually one-fifth to one-eighth that of the grate, or one-fifth to one-sixth the grate area when the top of the funnel is about forty feet above the grate.

24. METHOD OF SUPERHEATING STEAM.—"How is steam superheated, and what benefits are derived from it?"

Answer. Steam is superheated by passing through a system of pipes or coils that are placed in the smokebox for this purpose, and the steam in passing from the boiler to the cylinders absorbs the heat from the smoke and gases as they are drawn through the flues and stack, thus increasing its temperature. Superheated steam therefore gives a higher efficiency of the engine, as there is less loss of heat by condensation when it comes in contact with the walls of the cylinders. There are many types of superheaters, and the usual benefit derived from their use is claimed to be about 13 per cent higher efficiency.

25. SATURATED STEAM.—"What is meant by saturated steam?"

Answer. Steam in contact with the water from which it is generated is called saturated steam. Locomotives use saturated steam unless they are equipped with a "superheater," which is an appliance for heating steam on its way to the cylinders to a higher temperature than it had while confined in the boiler with the water from which it was generated.

26. Formation of Scale on Flues.—"We are using water from an artesian well in a stationary boiler, but a large quantity of scale forms on the flues. Will you please publish a preparation which will prevent the flues from scaling, or one which can be used to clean them? If kerosene oil is used will it make them leak?"

Answer. Soda-ash is the most universal "cure-all"; used judiciously and frequently, and blowing out of the boiler may prevent the formation of scale on flues. If you are unable to obtain treated water for boiler use, an analysis of the water should be made, then a compound can be prepared to prevent the formation of scale. Kerosene should not cause flues to leak.

THROTTLE AND STEAM CONNECTIONS.

1. Throttle Valve Leaking.—"Why does a throttle valve leak when boiler is full of boiling water and the valve is perfectly dry, with 200 pounds pressure of warm water?"

Answer. This is due to the expansion of the throttle valve and box, and the manner in which the valve is ground to its seat, as well as to the construction of same. A throttle valve with a small diameter of 5 inches and a large diameter of 5½ inches may be ground even, or both seats ground to a tight joint for water pressure, and will be perfectly tight when under steam pressure. But a larger valve with small diameter of 5¾ inches and a large diameter of 7½ inches, will, usually, be a better job, when the small end of the valve is ground to a tight joint and the large end of the valve ground to a loose fit, or so it would leak slightly under water pressure. Then when the boiler is under steam, expansion of the valve and box will take place and the valve that leaked under water pressure will be perfectly tight at 200 pounds boiler pressure at a temperature of 388 degrees. If it were possible to grind the throttle valves to their seats, at a temperature of the steam at working pressure, there would be no occasion to make allowance for expansion of the valve or box due to the difference in diameter and amount of metal in the valves.

2. Leaky Steam Pipe Joint Inside of Smokebox.—"What is the effect of leaky steam pipe joint inside of smokebox?"

Answer. The exhaust steam passing up through the

stack expels the smoke and gases from the front end, producing a partial vacuum in the front end. Air to supply this vacuum must be taken through the ashpan, grates, hollow staybolts, combustion tubes, and firedoor. If the steam-pipe joints leak, or the joint under the exhaust pipe, or if the steam from the blower pipe, exhaust pipe from the air pump or steam turbine for electric lighting are not directed up through the stack, but strike the flare of the petticoat pipe, or are tipped so that the leak or steam will destroy the partial vacuum, the engine will not steam and the fire will not burn brightly but will burn with a smoky dull red color.

3. Leaky Throttle or Dry Pipe.—"How can you distinguish between a leaky throttle and dry pipe?"

Answer. A leaky throttle or dry pipe will be indicated by steam escaping from the cylinder cocks when the throttle is closed. If steam escapes you should be sure that the steam valve to the lubricator is closed before deciding that the throttle is leaking. If the throttle is leaking there will be a constant flow of dry steam from the cylinder cocks, and if the dry pipe is leaking more or less water will be mixed with the steam. Much depends on the position of the dry pipe in the boiler. If it should be up near the boiler shell and the leak on the upper side of the pipe, the boiler should be well filled with water before the wet steam would show at the cylinder cocks. Test for the leaky throttle first with the steam valve of the lubricator closed. If dry steam is shown, increase the height of the water level in the boiler until the dry pipe is covered with water, and if dry steam still appears report throttle; if wet, report dry pipe. If dry pipe is not submerged, the location of leak can not be determined.

4. Leaky Steam Pipe Joints.—"Am firing a switch engine that is giving all kinds of trouble with leaky steam pipe joints. The engine has been taken in and joints reground, but they will not stay tight. Will you please say why?"

Answer.—If the joints are ground to a fit and properly tightened they should remain tight. Road engines in double header service when subjected to rough usage frequently give trouble of this nature, due to the stress and shocks caused by the leading engine tending to loosen the frames from the cylinders or the cylinders from the smokebox. A switch engine doing most or all of the work from the front end is subject to the same conditions as the second engine in the double-header service. A loose cylinder of a cylinder saddle that is not securely bolted to the smokebox will soon work the joints loose. If such is the case, remove the cause by reaming out the holes and applying new bolts that will fit and hold the parts rigid. A boiler that is fast or stuck in the expansion buckles or plates is also liable to give trouble. If the mud ring is on top of the frames, a few drops of oil occasionally on the expansion plates or knees may relieve it and prevent the mud ring from leaking.

5. Testing Steam Pipe Joints.—"What is the most accurate method of testing steam pipe joints for leaks when an engine fails for steam and you have reason to think that they are leaking?"

Answer.—A leaking steam pipe is usually indicated by the pressure running up to the blow-off point as soon as the throttle is closed and instead of having a bright fire when the engine is working it will burn a dull red or smoky fire, with the pointer going over to the fireman's

side of the cab. A very good way to make this test is to remove the petticoat or draft pipe if the front end is so equipped. Place a board and a piece of sheet rubber over the nozzle tip with the rubber between the board and the nozzle to insure a tight joint, set a jack on this and place a bar lengthwise in the smokebox under the stack and tighten the jack until sufficient pressure is put on the board to hold water. Then connect the boiler to the water system in the roundhouse, open the throttle, fill the boiler with water and put on pressure on the pipes, thereby obtaining the desired water pressure on the pipes and joints, as well as the joint at the base of the exhaust pipe. If leak exists the joint or pipe will be detected by the water running out of the leak. A sure thing when done right.

6. THROTTLE AND CUT-OFF. "What would you advise for best results in pulling a train, a certain stroke and a full throttle, or a little more stroke and less throttle? I find I can keep them hot the easier with more stroke and less throttle."

Answer. Would advise that the engine be worked where she will do the best. A short cut-off and a full throttle will not, as a rule, always prove as satisfactory with a high-pressure engine at slow speed as with the low pressures and small engines of years ago. It's as necessary for an engineer to have an ear for the sound of the exhaust and to manipulate the throttle and reverse lever to obtain work from the engine, as it is to have good eye-sight for the safety and handling of the train.

INJECTORS.

1. Principle of the Injector. "Describe as plainly as possible the principle upon which an injector works."

Answer. The principle upon which an injector works is a principle of induced currents. A current of any kind has a tendency to induce a movement in the same direction of any body with which it may come in contact. A blower or any steam jet acts on the same principle. With a non-lifting injector the steam does not raise the water to the injector, as the water flows to it and is forced into the boiler by the steam imparting a portion of its heat and velocity to the water and giving it a sufficient momentum to force it into the boiler. The steam entering the injector at a high temperature with great velocity strikes the cold water and is condensed, but imparts a large portion of the velocity to the water, sufficient for it to raise check valves and enter boiler at the supply tank, must raise the water to the injector, as a high pressure. A lifting injector, so called because the injector is usually set above the level of the water in the supply tank, must raise the water to the injector, as well as force it into the boiler. When the steam valve is open slightly on a lever injector, or the lifting valve, if the injector is of that type, the steam is permitted to flow out of the nozzle, directing it to pass out of the overflow pipe to the atmosphere, carrying with it the air from the supply pipe, thus creating a partial vacuum in the pipe between the injector and the water. Then the

atmospheric pressure on the surface of the water in the tank forces it into the supply pipe and out of the overflow pipe, thus priming the injector. Then when the steam valve is open, steam enters the injector in a much larger volume and, coming in contact with the water that is flowing through the injector, increases the velocity of the water which is forced into the condensing tube and out of the injector at the delivery nozzle with sufficient force to enter the branch pipe, lift the check, and enter the boiler. The steam and water flow through the injector and pipe at a high speed, forming a vacuum in the injector supply pipe and connections. Hence the importance of keeping them tight and free from leaks.

2. Action of Injector. "What makes an injector lift water?"

Answer.—With a lifting injector the injector does not really lift the water. The steam jet or primer allows the steam to flow into the overflow pipe and this forces the air out of the pipe and injector, producing a partial vacuum in the injector. This is one reason that all connections should be kept tight. When the air is forced out of the injector the atmospheric pressure on top of the water in the tank then forces the water up into feed pipe and into the injector. This also explains why injectors will work better at sea level than on mountains or at high altitudes, where the air is light and there is less atmospheric pressure to force the water up to the injector.

3. Injector Worked by Air Pressure.—"Can an injector be worked on a boiler with air pressure on it instead of steam? If not, why not? I have consulted several different engineers about it and they vary in opinion."

Answer.—No, it can not. The injector is an instrument that will force water into a boiler against a pressure equal to that of the steam that is used in its operation. Steam in forcing water through the injector and into a boiler gives up heat and imparts a velocity to the water, and starts it with a momentum sufficient to overcome a pressure even higher than the original pressure of steam. A great deal of the velocity of the steam is given up to the water, and gives the water sufficient energy to open the check valve and enter the boiler. As the steam condenses in imparting its heat and velocity to the water the pipe is solid full of water. When the water will not condense the steam or is too high a temperature (too hot) the injector will not work. Therefore, the reason that the injector will not work with air pressure is that the mixture of air and water would make bubbles and it would not be a solid body of water to absorb the velocity or mix with the air, as you could not have air and water occupying the same space at the same time. Our experience has been when reversing an engine and opening the throttle to prevent striking the rear end of a preceding train, that the injector always broke on account of the air mixing with the steam.

4. Obstructed Flow of Steam to Injector Throttles.—"I am firing a ten-wheel engine, cylinders 21x26 inches. Everything goes all right until it is necessary to put the second injector at work to keep water in the boiler. Then trouble begins; neither one will work satisfactorily and both throw water on the ground, but one injector will work at a time on either side. Injectors have been changed and repaired, with the same results. The main steam valve to the turret or combination valve is wide open and the other boiler attachments such as

blower, lubricator, and air-pump work all right. What is the trouble?"

Answer.—It is evident that the trouble is not in the injectors, as they will work all right when only one is used at a time. The reason for this is that they do not get a sufficient quantity of steam to force the water into the boiler. This may be caused by some obstruction in

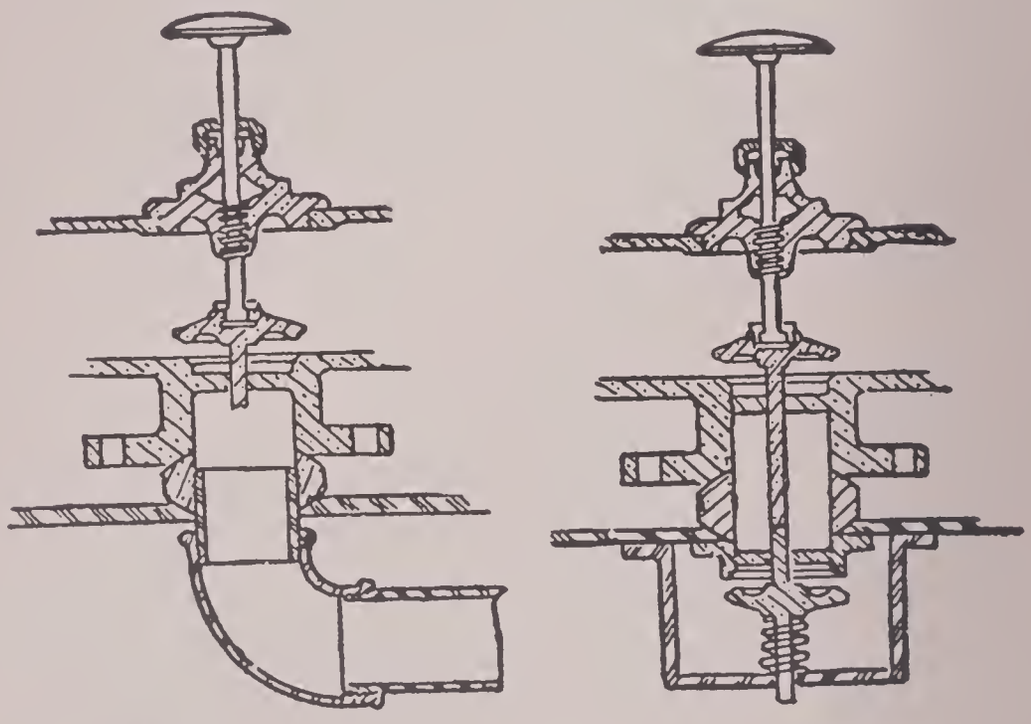


Fig. 1. Fig. 2.

Obstructed Flow of Steam to Injector Throttle.

the steam pipe leading from the dome to the combination valve or turret. A rivet, stud, or nut may have been dropped into the steam pipe, which would obstruct the flow of the steam from the boiler to the injector throttles, or the area of the opening leading from the boiler to the main valve is not large enough to equal the combined area of the valves for the other boiler attachments. This trouble sometimes occurs from the use of a combination valve that was designed for safety in case of accident.

The two illustrations show valves of the same exterior appearance. Note the one with the single valve, Fig. 1, which is fast to the stem, and can be opened wide open by raising it ¼ inch from its seat for every inch of diameter, and if then given a turn or two will do no harm. But the other, Fig. 2, with the double valve, should only be opened to about middle position, as shown in the cut. Should this valve be opened the same as the other it is obvious that the spring under the lower valve would force it to its seat and reduce the flow of the steam, if it did not shut it off entirely, so that both injectors would not work at the same time, because there would not be enough steam to do the business. The effect of the restriction would not be as apparent on the action of the blower, air-pump, and lubricator, although if they get a liberal supply of steam to the turret they will work much better.

5. Freezing of Injector Delivery Pipe.—"Explain how the water in the delivery pipe can be protected from freezing."

Answer.—By using the heater, having the steam valve slightly opened, with the overflow valve closed, steam will flow back into the tender through the feed pipe and at the same time flow forward into the branch pipe. The heater cock should be opened to drain the condensed steam or water from the delivery pipe, otherwise it will fill with water and freeze. The steam valve should not be open so far as to cause water to become overheated in the tender, preventing the injector from working or damaging the paint on the tender.

6. Freezing of Injector Waste Pipe.—"Explain how you would prevent the waste-pipe from freezing either while the injector was working or shut off."

Answer.—Open the overflow valve occasionally to prevent the pipe from freezing. This will allow steam to go through it and keep it warm.

7. LEAKY CHECK AND INJECTOR STEAM VALVES.—"How may it be determined whether the check valves or steam valves are leaking on an injector?"

Answer.—If the steam valve leaks it will show steam only at the overflow or waste pipe of the injector, but if the check valve is stuck open or is leaking, water will come out with the steam, indicating that the leak is in the check. Open the frost cock on the branch pipe and the temperature will indicate that it is the check that is giving the trouble. Steam valves are located above the water level and the check valves below the water level in a boiler.

8. LEAKY CHECK AND INJECTOR THROTTLE VALVES.—"Will injector prime if checks leak bad or are stuck up, or if throttle valve leaks bad?"

Answer.—If the check leaks bad and there is no line check in the branch pipe, the steam and hot water will flow back into the injector and prevent a vacuum being formed to raise the water to the injector. If the throttle leaks bad you will have the same trouble. Sometimes injectors have been started when throttle or checks were leaking, by throwing cold water on the checks or injectors, thus condensing the steam so that they would prime and bring water up to the injector.

9. LEAKY PRIMER VALVES.—"Will the injector prime if the primer valves leak? Will this prevent its working?"

Answer.—No. The primer valve leaking will only cause the injector to prime when not wanted, but would not interfere with the working of the injector when steam

was turned on to force water into the boiler. To prevent waste of water, close water valve or tank valve.

10. Leak between Injector and Tank.—"Will an injector work with a leak between the injector and tank? Why? Will it prime?"

Answer.—A nonlifting injector will work if there is a leak between the injector and tender, providing there is a sufficient supply of water flowing into the injector feed pipe. A lifting injector will not work if there is very much of a leak, as the air enters the pipe and prevents the injector from forming the necessary vacuum required to raise the water to the injector. It will not prime. Even if it does prime the injector will not work to its full capacity. Close the overflow and put on the heater. This will show where the leaks exist, and have it made tight if possible.

COMPOUND LOCOMOTIVES.

NOTE:—For a complete treatise on compounds and upon the Balanced Compound see another volume of this work.

1. Horse-Power of Vauclain Compound Locomotive.—"What is the horse-power of a Vauclain compound locomotive, cylinders 19 and 32 inches by 32 inches, speed 30 miles per hour, M. E. P. 225 pounds, and wheels 57 inches in diameter?"

Answer.—We infer that the boiler pressure is 225 pounds, and that you may wish to use this information on other sizes. The following formula is used to find the tractive power for a Vauclain 4-cylinder compound locomotive for different speeds:

$$\frac{C^2 \times S \times 2\text{-}3\,P}{D} + \frac{c^2 \times S \times 1/4\,P}{D} = T.$$

C = Diameter of high pressure cylinder in inches.
c = Diameter of low pressure cylinder in inches.
S = Stroke of piston in inches.
P = Boiler pressure in pounds.
D = Diameter of driving wheels in inches.
T = Tractive power.

The tractive power multiplied by the speed in miles per hour divided by 375, gives the horse-power.

2. Disconnecting Compound Locomotives.—"In case it was necessary to disconnect on one side of a Vauclain compound locomotive, how would you cover the ports and hold valve in position? How with a tandem?"

Answer.—With a Vauclain compound would place the valve in the center of its seat, covering all ports of for admission, and clamp it in that position. With a tandem would employ the same methods as with a simple engine.

3. DISCONNECTING A VAUCLAIN COMPOUND OR TANDEM.—"How would you cover ports and hold valve in position when disconnecting a Vauclain compound, and how with a tandem?"

Answer.—Cover ports same as with a simple engine, by placing the valve in the center of its seat and clamp securely. Employ the same method with a tandem.

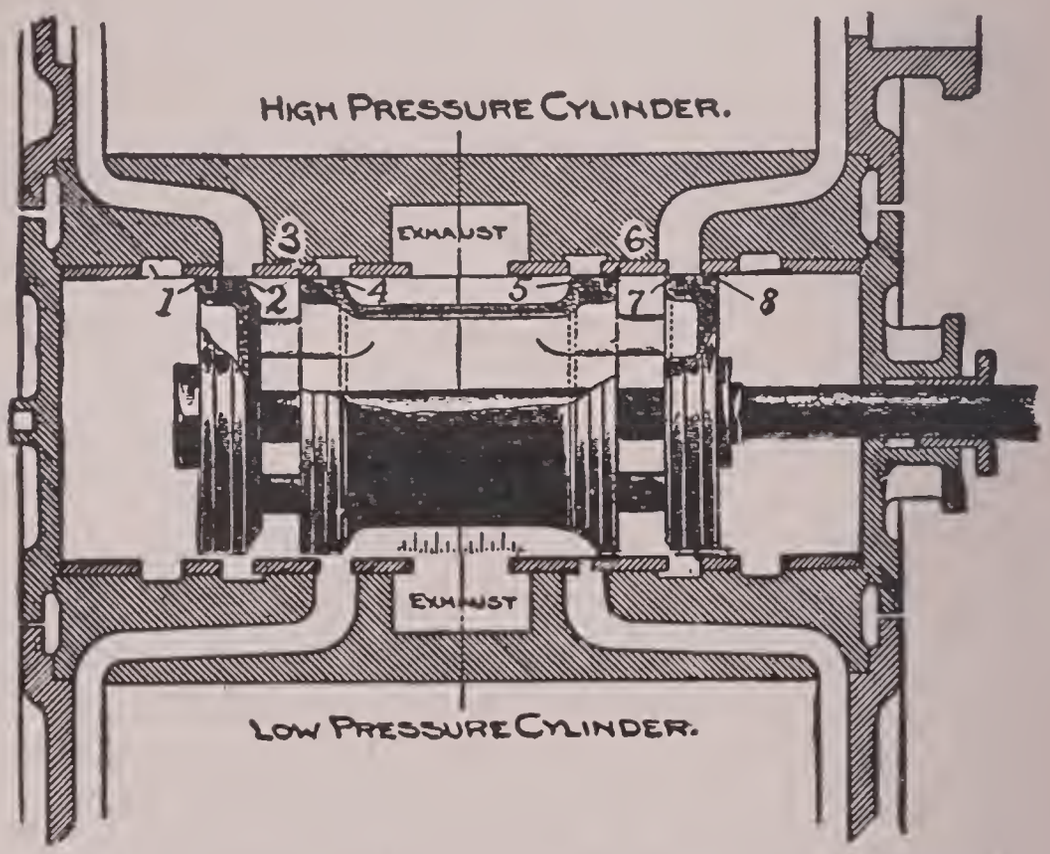
4. TESTING FOR BLOWS IN COMPOUNDS.—"How would you test for a valve blow in a Vauclain compound? How with a tandem? How for high and low pressure cylinder packing, each type, and several others, regarding compounds?"

Answer.—The detection and location of blows in any engine is not always an easy thing to do at all times and more difficult on a compound, and mechanical officers should not expect too much from enginemen.

5. TESTING FOR VALVE BLOWS IN A VAUCLAIN FOUR-CYLINDER COMPOUND.—"How would you test for a valve blow in a Vauclain four-cylinder compound? There are eight packing rings; I can get the high-pressure valve rings, but how would you test for the low-pressure packing rings?"

Answer.—It is very difficult to distinguish the difference in blows, as there are several different defects about the Vauclain compound that will produce the same effect on the valve motion or the sound of the exhaust, and care should be taken not to mistake two light exhausts on one side for two heavy exhausts on the other. One loud exhaust with the Vauclain compound may be

caused by either rings *Nos.* 1, 2, 3, 6, 7 or 8 being broken. Rings *Nos.* 1 or 8 broken, gives more port-opening at the end of the high-pressure cylinder that the ring is broken on. This goes to the opposite end of the low-pressure cylinder and produces a heavy exhaust. If rings *Nos.* 3 or 6 are broken, the volume of steam admitted to the low-pressure cylinder is increased with the same effect. Rings *Nos.* 2 or 7 being broken will give



Testing for Valve Blows in a Vauclain Four-Cylinder Compound.

one heavy exhaust on that side of the engine, as the steam will blow past the ring from the live steam-way directly into the hollow of the valve, when the steam port at the opposite end of the valve is open. If there is a heavy exhaust from the front end of the right side it may be caused by rings *Nos.* 8 or 2 being broken, thus increasing the pressure in the low-pressure cylinder, and

you get a heavy exhaust. The illustration and method of making standing tests, taken from their report is as follows: Place engine on bottom quarter on side to be tested; block the drivers or set brakes, and remove both indicator plugs on high-pressure cylinder. If engine is not equipped with plugs, remove pops or water relief valves on the cylinder heads; give the engine steam and be sure that the throttle is open sufficiently to set packing rings out against bushing. If ports can be covered, this shows rings 1 and 8 are in good order. In testing for high-pressure packing blow, put the reverse lever in forward motion, which will open front port to the high-pressure cylinder; close the starting valve and have the indicator plug or pop out at the back end of the high-pressure cylinder. When steam blows out of the indicator plug, the high-pressure packing may be blowing or ring *No.* 7 be broken. To determine which this is, replace the indicator plug in back end and remove the front one, put the reverse lever in the back motion and make same test. If it is the high-pressure packing that is blowing, it will show; if it is ring *No.* 7 it will not show. To test for low-pressure packing, put the reverse lever in forward motion with all indicator plugs in except the one in the back end of low-pressure cylinder. Open the starting valve, which will admit steam to back end of high-pressure cylinder, hollow of valve and front end of low-pressure cylinder. If low-pressure packing blows, you will note it at the back of the indicator plug. In this same position, if rings *Nos.* 3 and 4 or 5 and 6 are broken, steam will blow through the stack. The blow will be light in either case, as the steam, to produce it, must come through the starting valve.

6. Broken Intercepting Valve.—"What would you

do with broken intercepting valve on following engines: First, Schenectady compound; second, Richmond Compound; third, Pittsburg compound? This applies to the intercepting valve being broken so nothing could be done with it."

Answer.—We will assume that our correspondent does not mean exactly what he says, for, if the valve were so badly broken that nothing could be done with it, that would naturally settle it.

Taking the first part of the question, what would you do with a broken intercepting valve on a Schenectady compound? The intercepting valve, if it breaks at all, usually breaks through the nib, so that the end ahead of nib can turn so that the receiver can not be shut off from communication with the low-pressure steam chest. When the throttle is opened live steam from the small steam pipe will pass through the reducing valve and into the low-pressure steam chest, but as the front end of the intercepting valve is broken off, the passage in front of the bridge in the receiver is open, consequently this live steam can back up in the receiver and into the exhaust end of the high-pressure cylinder, so that the pressure on both sides of the high-pressure piston will be balanced, consequently if the engine should happen to be standing with the low-pressure side on the dead center, the engine would be powerless. If your engine should act in this manner, first look at the dash pot piston rod. If this shows that the intercepter is ahead, open the cylinder cocks. If steam flows from both high-pressure cocks and also from one low-pressure cylinder cock, open the separate exhaust valve. If steam blows violently at the stack you can be sure that the intercepting valve is broken, and if you will look at the dash pot you will see the cause—dash pot empty.

To get started, close the throttle, keep the separate exhaust valve open until all the steam is out of the receiver, then close the separate exhaust valve, fasten the intercepter back so as to prevent the admission of live steam through the reducer and go on. In stopping try to stop with the engine on the quarter on the high-pressure side, as in this case the engine will only work compound, and consequently no steam will enter the low-pressure cylinder until the high-pressure side exhausts.

In case the engine should stop on the center on the high-pressure side under such circumstances, you need only loosen the intercepting valve and the live steam will flow into the low-pressure cylinder in the usual way and start the engine, and as soon as the receiver pressure runs up, the intercepting valve will go back into compound position again.

Assuming, however, that our correspondent meant what he said, viz., that the intercepting valve was "all shot to pieces." In this case you could not prevent live steam from flowing through the small steam pipe into the exhaust end of the high-pressure cylinder and so blocking the engine. The only thing to do in a case of this kind if you want to use both sides of the engine, would be to take out the broken pieces of the intercepting valve and block the steam port leading from the small steam pipe by driving a big block into the bushing in place of the intercepting valve, so as to prevent any live steam from entering the low-pressure cylinder. In this case the engine would only work compound, and if you got stuck on the center on the high-pressure side it would be necessary to pinch her off. The engine might also be brought in light with a smashed intercepting valve by simply opening the separate exhaust valve, but

it would be mighty hard on the fireman, as all the steam from the small steam pipe would pass directly from the boiler to the stack. The engine would be practically on one side (high-pressure).

Passing to the second question, broken intercepting valve on a Richmond compound. About the only thing that would be at all likely to break would be the end of the valve. In this case the engine would compound herself as soon as the receiver pressure ran up. In this case, same as with a Schenectady compound under similar circumstances, you would have to depend on the low-pressure side to start the engine, in case the engine stopped with the low-pressure side on the center. Proceed same as with the Schenectady type, by exhausting all the steam from the receiver by means of the separate exhaust valve, etc., as explained above.

In case the intercepting valve were all broke to pieces, it would be necessary, same as with the Schenectady type, to stop the flow of live steam from the small steam pipe into the low-pressure steam chest, by slipping a blind gasket over the port in the intercepting valve cage outside of the cylinder saddle. In this case the engine would only work compound, and in case you got stopped on the center on the high-pressure side you would have to remove the blind gasket to get started. This engine could also be run in light with a badly broken intercepter by simply opening the separate exhaust valve.

Third question same as the others, only with a Pittsburg compound. Even if the intercepting valve in this type of engine were badly broken it would be almost impossible for the pieces to get away, and so long as there is enough left to blind the high-pressure emergency exhaust the job is easy. Tighten up on the stem of the re-

ducing valve to insure its remaining closed. Disconnect the connecting rod to intercepting valve and push the valve clear ahead, clamping it there, and go on. If the intercepting valve is so badly broken, however, as to leave no piece large enough to cover the emergency exhaust port, it will be necessary to take out the pieces and block the emergency port by means of a round block slipped into the intercepting valve bushing. In both cases the engine would work strictly compound, and the high-pressure side must be depended on to start the engine. If, however, the engine did stop with the high-pressure side on dead center the emergency or reducing valve could be used by slacking it up again.

7. Low-pressure Side Demolished.—'What would you do if the low-pressure side on a Richmond compound became demolished so the valve could not be used?"

Answer.—We presume our correspondent means that the cylinder be broken off entirely. If the cylinder saddle and intercepting valve is not damaged, take down all broken parts on the disabled side, slip a blind gasket over the steam port leading from the small steam pipe to the reducing valve chamber, block the intercepting valve shut and proceed with high-pressure side with what you can handle. On account of the restricted opening through separate exhaust valve the best speed you can make with a train will be about 8 or 10 miles per hour.

8. Proper Position of Intercepting Valve in Bushing.—"Can you give the proper position of the intercepting valve in the bushing, and what position should the filling plug on the oil pot be on an angle; facing upwards to the left or right side of engine? If the intercepting valve were put in on the wrong position, what effect would it have on the working of the engine?"

Answer.—At the right-hand end of the intercepting valve an opening has been cut. This opening should always be on top, and if the valve is put in correctly it will be.

The position of the filling plug on the oil dash pot faces upward and 30 degrees to the right.

In regard to the intercepting valve being put in wrong, the question was submitted to Mr. F. E. Cole, mechanical engineer of the American Locomotive Company, who replied as follows:

"The only way in which we can see a possibility of an incorrect application of the intercepting valve would be to apply the heads in an upside-down position. To do this the dowel would have to be omitted. If the valves were thus put upside down, the engine would work neither simple nor compound, as the receiver pressure could not act on the end of the valve to open it, because the opening in the end of the valve would be on the bottom; neither could it work simple more than a few strokes, as the exhaust from the high-pressure cylinder could not get out of the receiver by way of the separate exhaust valve."

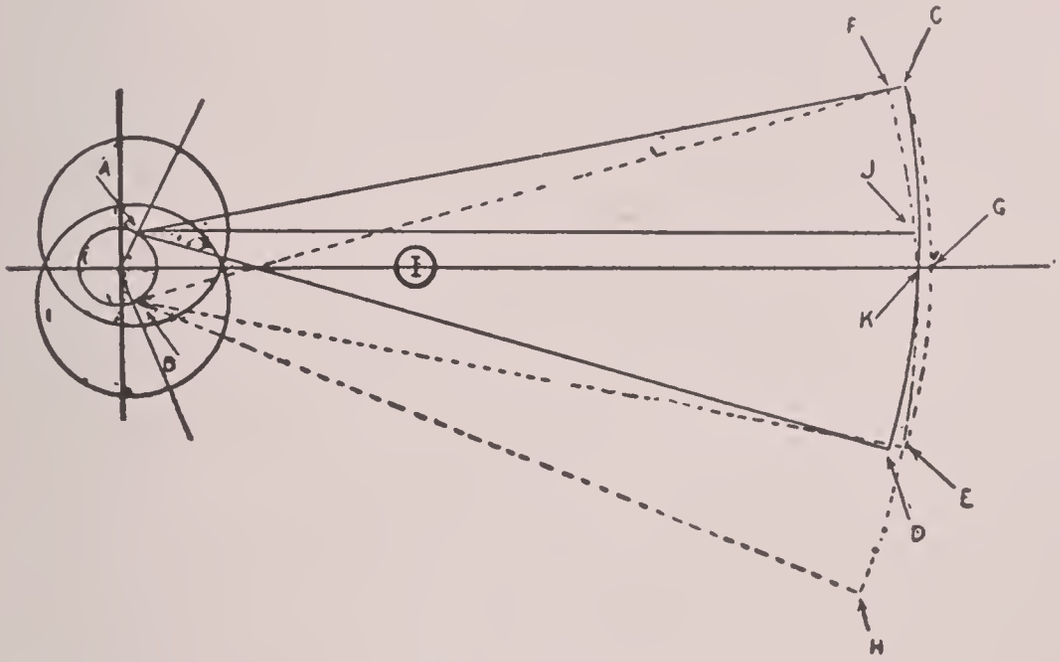
If the heads were put on wrong on account of the dowel being left out or broken off, it would place the filling plug for the oil dash pot on the bottom, a mistake that should be at once apparent, unless the man putting in the intercepting valve should mistake the regulating plug for the filling plug, in which case the mistake should also be noticed when attempting to fill the oil dash pot.

9. Increase of Lead by Hooking Up Lever.—"Explain why lead increases as the reverse lever is hooked up?"

Answer.—The increase in lead is due to the action of

the backing eccentric when lever is near the center in the forward motion, and to the go-ahead eccentric when lever is near the center in the back motion.

In order to understand this better we refer you to the sketch herewith. This sketch shows the position of the two eccentrics on the shaft with engine on the forward center, as shown by crank pin *I*. The points *A* and *B* are the centers of the forward, or go-ahead, and the back-up eccentrics respectively.



Increase of Lead by Hooking up Lever.

In order to overcome the lap of the valve and give the engine the lead required the two eccentrics are advanced toward the crank pin *I* as shown. Now, if both blades were coupled to the go-ahead eccentric the link would occupy the position shown by the full lines *C-D*, and the link could be swung throughout its range without increasing the lead, but by dropping the back-up blade to its true position and coupling it to the back-up eccentric the link is pushed forward as much as the eccentric has

been moved toward the pin, and the link will therefore occupy its true position as shown at *E-C*. As the link is carried forward it of course carries the bottom end of the rocker arm with it, pulling the top end back and thereby increasing the lead in mid gear.

When the reverse lever is full forward gear the link is in the position shown at *J-H*, and the back-up eccentric does not affect the lead, as is shown by the intersection of the lines *F-H* and *C-D*. Raising the link, however, brings the back-up eccentric into play and the link is advanced as shown at *G*. The same thing takes place when the reverse lever is thrown into full back gear, in which case the go-ahead eccentric has no effect on the movement of the valve; bringing the lever forward toward the center, however, again throws the go-ahead eccentric into play and advances the link as before. As shown in sketch, the nearer the link is brought to its mid gear position the greater the increase in lead.

10. Broken Side Rod on Baldwin Balance Compound Locomotive.—"We have a few of the Baldwin Balance Compound Locomotives; they are the four-wheel connected. The high pressure rods are connected to the front drivers and the low pressure rods are connected to the back drivers, the eccentrics are on the back axle. Now if we were to break a side rod, what are we to do to get the engine in? This question has come up and there is considerable discussion on the matter."

Answer.—The Baldwin Locomotive Company recommend that in a case of this kind, where the high pressure cylinders are connected to the front axle and the low pressure cylinders to the second driving axle, the eccentrics being on the second axle, if the side rod breaks on an engine of this type the high pressure pistons should

be removed and the engine run in with the low pressure cylinders. Under these conditions she will run as a single expansion engine; the high pressure cylinders merely serve as steam chests for the low pressure cylinders.

11. Broken Driving Spring or Hanger on Schenectady Compound.—"If you break a driving spring hanger or a spring on a Schenectady compound, what would you do?"

Answer.—The boiler, frames, truck, and driving wheels are the same on a compound as on a simple engine, the only difference being in the arrangement of the cylinders, pistons, crossheads and valves. A breakdown of this nature should be handled in a similar manner. In order to answer this question correctly would require description of spring rigging, and type of engine.

12. Broken Cylinder Head on Schenectady Compound.—"If you blew out high-pressure cylinder head on a Schenectady compound how would you disconnect? If a low-pressure cylinder head, how would you disconnect?"

Answer.—The instructions of the American Locomotive Company are: "Should the high-pressure side become disabled, disconnect, block, cover the ports and open separate exhaust valve same as when running simple. Should the low-pressure side become disabled, block, cover the ports and open separate exhaust valve." In case the engine should be without air for the operation of separate exhaust valve a block, preferably of wood, about three inches thick, should be used, inserted in the valve cylinder by removal of the head and the head again replaced over the block.

13. Broken Steam Chest on Two-Cylinder Schenectady Compound.—"What should be done if right-hand steam chest breaks on one of the two-cylinder Schenectady compounds?"

Answer.—In case a low-pressure steam chest is broken use the high-pressure side as a simple engine. To do this you will have to take out the intercepting valve and block the reducing valve in closed position, so that when the intercepting valve is replaced no steam can get to the low-pressure side when intercepting valve is in simple position.

14. Broken Stem of Intercepting Valve.—"If you break the stem off the intercepting valve on a two-cylinder Schenectady compound; what would you do?"

Answer.—A break in the intercepting valve means running the engine simple, after valve has been blocked to allow this. This can easily be done by clamping the stem or rod, but if not, remove the head and insert a block to hold the valve in place and replace the head.

15. By-Pass Valve on H. P. Side of Schenectady Compound Broken.—"How would you locate a broken by-pass valve on high-pressure side of a Schenectady compound and how remedy it?"

Answer.—To locate a defective by-pass valve on high-pressure side, follow the same course as with low-pressure side, except that in this case open the separate exhaust valve by placing the three-way cock in simple position. A blow from a broken by-pass valve can be easily distinguished from other blows on account of its being a very strong one and only occurring during one stroke of the piston. For example: If the blow occurs during the forward stroke, the defect would be in the forward valve. The best way to remedy it is to remove the

by-pass valve casing from the side of the cylinder and cover both openings with a thin copper or sheet-iron gasket and replace the casing.

16. By-Pass Valve on L. P. Side of Schenectady Compound Broken.—"How would you locate a broken by-pass valve on low-pressure side of a Schenectady compound, and how remedy it?"

Answer.—To locate a defective by-pass valve on the low-pressure side of a Schenectady two-cylinder compound, place engine on upper quarter on low-pressure side, reverse the lever in forward motion. Close separate exhaust valve by placing three-way cock in compound position and admit steam to cylinder. If blow occurs from exhaust, defect would be in forward by-pass valve. If blow occurs with lever in back motion, engine in same position, defect would be in back by-pass valve.

17. Blow in Low-Pressure Cylinder of Schenectady Cross Compound.—"How would you test for a blow in the low-pressure cylinder of a Schenectady cross compound?"

Answer.—Make test for blow in low-pressure cylinder by moving the handle of the operating valve to simple position, and test in the usual manner as for simple engine.

MISCELLANEOUS.

1. Calculating the Horse-Power of an Engine.—"In the study of steam engineering I find two different methods of calculating the horse-power of an engine which, according to my figures, do not give anywhere near the same results, and I would be pleased to have your opinion as to which is correct. The rule given by Hawkins in his study of the steam engine is as follows: 'Multiply the area of the piston in square inches by the average force of steam in pounds and by the velocity of the piston in feet per minute and divide the product by 33,000 pounds. Seven-tenths of the quotient equals the effective power.' The other rule is: 'Multiply the mean effective pressure on the piston by the length of its stroke in feet. Multiply this product by the area of the piston in square inches, and multiply again by the number of strokes per minute, dividing the last product by 33,000 pounds,' or, in other words, the P L A N method. Your example:

P = 82 pounds steam pressure during length of stroke.
L = 3.5 feet, length of stroke.
A = 907.922 square inches, area of piston.
N = 45 strokes per minute.
In this example:

$$\frac{P\,L\,A\,N}{33{,}000} = \frac{82 \times 3.5 \times 907.922 \times 45}{33{,}000} = 355.3 \text{ H. P.}"$$

Answer.—The rule given by Hawkins is identical with

the above. Therefore both rules are correct. This is termed the indicated horse-power, and designates the work done by the steam. In taking seven-tenths of the quotient in either case you have 248.71 horse-power, which expresses the total available power of the engine, thus allowing three-tenths to overcome the friction of the engine, as the available horse-power is less than the indicated horse-power the amount that is absorbed in overcoming the resistance and friction of the engine. In one formula you made allowance for this and in the other you did not, which accounts for the difference.

2. Weight on Drivers and Tractive Effort.—"Does the term 'weight on drivers' mean also the weight of the drivers, journals and pin connections in figuring the tractive effort? If not, why not? Why, in figuring the tractive effort, do you take only one side of the engine instead of both cylinders?"

Answer.—The adhesion of a locomotive is the friction between the driving wheels and rails and depends upon the weight or pressure of the surfaces in contact. Therefore, the weight on the drivers means the weight of the driver and the load resting on it at its point of contact with the rail. The weight on drivers is usually limited by the engineering department and depends on the weight of the rails, condition of the roadbed, strength of the bridges, etc. If the weight of the drivers was not included in placing the limit, the engine would be hard on the track and increase the cost of maintenance of roadway and bridges. A pair of drivers will weigh from 6,000 to 9,000 pounds, and as they add to the adhesion, it should be figured from the point of contact with the rail. The use of the dynamometer car is the most accurate method to obtain the drawbar pull or tractive power of a

locomotive. This is a car especially fitted with a drawbar connected with calibrated springs that indicate the number of pounds pull on the drawbar. In answer to a similar question we found a tractive power of 22,674 pounds for an 18x26-inch engine with a 60-inch wheel and 190-pound boiler pressure. If we desire to obtain the tractive power by figuring both pistons or both sides of the engine, the following formula should be used instead, which gives nearly the same results. To make the example clear to all we will give the figures. Area of one piston (which = 254.4696 square inches) times the pressure in the cylinders (which = 161.5 pounds) times twice the length of the stroke (which = 4.3333 feet) times 2 (for both pistons or both sides of the engine), divided by the circumference of the wheel, equals tractive power of 22,686 pounds. A slight difference, but either is accurate enough for general application and the one cylinder method is the shortest, therefore most used in calculation. If the weight on the drivers is known, one-fourth of the weight is usually taken as the tractive power. In the above, would expect the weight on the drivers to be about 91,000 pounds.

Should we desire to figure the tractive power with the two-cylinder or both piston method, we would use the following formula: Area of one piston (in this case = 254.4696 square inches) times the pressure in the cylinder (which = 161.5 pounds) times twice the length of the stroke (which = 4.3333 feet) times 2 for both sides, divided by the circumference of the wheel (which = 15.7 feet), we have:

254.4696
161.5 pressure

12723480
2544696
15268176
2544696

41096.84040
4.3333 Twice the stroke in feet

12329052120
12329052120
12329052120
12329052120
16438736160

178084.938505320
2 For both pistons

356169.877010640

Divided by the circumference of the wheel in feet, we have:

15.7) 356169.877010640 (22685.9+
314
421
314
1076
942
1349
1256
938
785
1537
1413
124

3. Per Cent of Heat Used.—"Will you kindly give me the per cent of heat used and the per cent of heat that escapes from the stack of a locomotive while working?"

Answer.—In order to make this clear we will have to take an example and work out the answer. Conditions vary so much that the answer will only be approximately correct for this specific case.

We will assume that we have an engine with 22x27-inch cylinders; driving wheels 56 inches in diameter, with a boiler pressure of 175 pounds, and running at a speed of 12 miles per hour. Allowing a mean effective pressure in the cylinders of 78 per cent of the boiler pressure we would obtain a tractive power of 33,000 pounds, or the locomotive would develop one horse-miles per ton of coal at 12 miles per hour, it would be equal to 1,056 horse-power. If the engine run 15 miles per ton of coal at 12 miles per hour she would burn twenty-six and six-tenths (26.6) pounds of coal per minute. Now all the energy that we are to get from the engine is stored in the coal, and is called heat units. The mechanical equivalent of a heat unit, expressed British thermal unit (B. T. U.), when changed to work is equal to 778 foot-pounds of work. Then, figuring that one pound of coal contains 11,660 B. T. U., or heat units, we would have stored in twenty-six and six-tenths (26.6) pounds of coal 7,320 horse-power if all the heat units could be converted into work. But as they can not we will have the difference between the energy taken from or liberated from the coal by combustion and the energy delivered to the drawbar to overcome the train resistance, which would be 7,320 and 1,056 horse-power, respectively, or about fourteen and four-tenths (14.4) per cent of the heat in the coal used.

4. Engine Supports.—"At what point is an engine supported in working order?"

Answer.—Supported on the rails first. The frame and the boiler resting upon it is supported at the engine truck center in front and at the fulcrums of the equalizers, and from these points of suspension the weight is transferred through the equalizers and springs to the spring saddles which rest directly on the driving boxes.

5. Finding Diameter of Circle for a Given Area.—"Give a rule to find the diameter of a circle when the square inches of its surface only are known."

Answer.—Suppose you desired an area of 12 square inches and wished to determine the diameter of a circle that would contain 12 inches area: 12 inches divided by .7854 = 15.278, and the square root of 15.278 = 3.908 inches, the diameter of a circle that will contain 12 square inches of area. Written thus:

$$\sqrt{\frac{\text{Area}}{.7854}} = \text{diameter of circle.}$$

6. Indicator Cards.—"What are the four principal points of an indicator when indicating an engine?"

Answer.—If you mean the four principal points of an indicator card, they are the admission, cut-off, expansion and release or exhaust. If the pencil of the indicator is held to the paper on the indicator drum when communication between the cylinder and indicator is shut off, both sides of the indicator piston are exposed to the atmosphere and a line is made on the paper that has no connection with the conditions existing in the cylinder. This forms the line from which all other pressures are determined. Now before taking the card it is well to allow the piston in the indicator to make a few strokes before

applying the pencil to the paper, this to warm up the pipe leading to, and the cylinder of the indicator. Then when the pencil is applied it will indicate the admission line, which will show the pressure in the cylinder until the pencil begins to fall, or the valve has closed the port for admission of steam. This is the point of cut-off, and shows that the valve has closed the port for admission. As the steam expands in volume the pressure decreases, and the drop of the pencil, showing the drop or decrease in pressure indicates the expansion of steam in the cylinder until the port is opened for the release or exhaust, and then the pencil falls until the cylinder piston reaches the end of its stroke, and as the piston now moves forward, if the steam did not all get out of the cylinder the piston will push it out, and the line made by the pencil will indicate the pressure on the exhaust side of the piston, which is called the back pressure, and is measured by its distance above line the first made on the card. This line continues until the valve closes the exhaust, when the line will curve upwards, showing that the steam did not all get out of the cylinder, and what failed to escape through the exhaust port was compressed in the cylinder. Therefore, we have a card showing admission, cut-off, expansion, release, and compression—five important points.

7. Locomotive Whistles.—"What makes the whistle on a locomotive sound? Is it the steam cutting on the edge of the whistle bell or not?"

Answer.—Yes, the bell of the whistle should come directly over the circular opening in the cup so that the steam escaping through the circular opening will strike the thin edges of the bell. This gives the bell of the whistle a vibrating motion and generates a deep sound, the

tone being dependent on the length of the bell or barrel of the whistle. If a long barrel is used on the whistle the vibrations will be longer, and it will be termed a coarse, or bull whistle. By placing a block inside the barrel, or reducing its length, the whistle will be more shrill or ear splitting as the vibrations are shorter. The chime whistle consists of a bell with three compartments of different lengths which produce three distinct tones pitched to the first, third and fifth tones of the musical scale, which gives an agreeable musical chord by the vibrations of each blending together.

8. Transmission Bar vs. Long Valve Stem.—"We have a class of engine on our division with short eccentric rods in connection with the transmission bar. The division that we terminate with have Pacific type of locomotives which are equipped with short eccentric rods and long valve stems. I have listened to many arguments on the speed of the two different types of engines. A. says that an engine with a long valve stem can acquire the same speed that an engine with the transmission bar can, and B. says that she can't. Now, who is right?"

Answer.—If the valve gear, valves, size of steam ports and passages, length of eccentric rods, etc., are identically the same, and the only difference is that one engine has a transmission bar and the other has not, with valves set the same on both engines and the same distribution of steam, it is our opinion that one would run equally as fast as the other. The valve gear simply gives the valve its movement for the admission and exhaust of steam to and from the cylinders, and on like engines the only difference would be the friction of the gear in this case.

9. Disconnecting Engine.—"What else could be done on one of the most important passenger trains while

ascending a grade about 75 miles out on a trip? I first broke piston valve, and before I could make a stop broke both the eccentric straps, blades and link hanger on that side, and knocked off the MacIntosh blow-off cock; the boiler was so full of mud that the blow-off cock did not leak. When the broken eccentrics were removed I could not move the valve, and the back port was open, so took down the main rod and blocked the cross-head forward. Took the train 108 miles on one side, and made eight stops for stations and railway crossings, arriving 240 minutes late at terminal. Something happened so that the back cylinder head was broken when I got in. I thought that I did fine, but the 'Old Man' can not see it that way. Will you please give me all the information you can on this?"

Answer.—Not being on the engine at time of the failure, but judging from the above, it would appear that the eccentric strap or link hanger broke first, which allowed the valve to move beyond its full travel, and the valve got stuck in the bushing or a broken ring got into the port, which would prevent its being moved back. Then with the back port open the main rod certainly had to be taken down. This is often a difficult piece of work on the track with the tool equipment usually found on locomotives at the present time, and much depends upon the condition of the rod bolts. Cases of this kind have come under the observation of the writer, where, with the help of the section gang and train crew, more than an hour was consumed, and he has seen the bolt sheared so that it required drilling out when the engine arrived at shop.

After you were ready to go on one side time could not be made, and in starting the train minutes were lost that could not be made up. While the time consumed taking

down the rod, size of engine, weight of train and schedule of same are not given, we are of the opinion that the work performed by the engine crew in this case is more creditable than otherwise. Master mechanics sometimes escape being placed in embarrassing positions by not being on the ground and having a finger in the pie in a serious delay like this.

The proper thing to have done would have been to furnish another engine, but if none was available it was no fault of the crew. That you did as well as stated shows that you met the emergency when it came up the best you could with conditions against you, and we cannot criticize your work.

The reason that the MacIntosh blow-off cock did not leak was not on account of mud, but because the check valve there for that purpose found its seat and prevented the water from escaping from the boiler, when the part of the blow-off cock outside the boiler shell was broken off. The back cylinder head being broken could not have shown much of a leak until after you arrived at the terminal, and it is not an uncommon thing to find cylinder heads cracked on inspection in roundhouse.

10. Proportionate Area of Safety Valve to Grate Area.—"Will you please work out in full the following examples. With 1 square inch of valve area to 3 square feet of grate area, what size safety valves should be used on a boiler having a firebox 116 inches long and 89 inches wide?"

Answer.—A firebox 116x89 inches would have a grate area of 89 times 116 = 10,324 square inches, or 71.69 square feet. One square foot contains 144 square inches, and 3 square feet = 3×144, or 432 square inches. Dividing 10,324 by 432 gives 23.9 square inches of safety valve

area. Therefore, with 1 square inch of valve area to 3 square feet of grate area we would require safety valves that would give an opening of 23.9 square inches. A 3¼-inch safety valve would have an area of 8.2958 square inches, and three 3¼-inch safety valves would be ample, as per the above question. It is customary to base the area of the safety valve opening on the evaporation of water per hour or minute, rather than on the size of the grate area.

11. Burned or Broken Grate.—"How would you manage with a burned or broken grate? How if entirely gone, with deep ashpan?"

Answer.—If a grate was broken you might be able to block up under it so as to bring in your train. But it is usually better with a grate burned, broken or entirely gone, to place angle bars across the space to keep coal from falling through into the ashpan. Keep the ashpan clean and you will be reasonably free from grate troubles.

12. Lining Up a Stationary Engine.—"How would you proceed to line up a stationary engine?"

Answer.—Remove the cylinder head, piston and rod, stuffing-box gland, cross-head and connecting rod, and turn the crank to the lower quarter. First place a level on the shaft and level it, if need be, by raising or lowering the outboard bearing, as the case may require. Fasten one end of a stout cord or, better still, a fine wire to some object beyond the crank and pass the other end of wire through the stuffing-box and cylinder and fasten to some object as before. With a pair of inside calipers take the distance between the walls of cylinder and the wire at each end of the cylinder and also at one or more intermediate points, for the purpose of bringing the wire into the exact center of the cylinder. When the wire occupies a

perfectly central position throughout the length of the cylinder, turn the crank around until the crank pin just touches the under side of the wire. When the pin occupies this position the distance from the wire to the inside of the shoulder or collar on pin should be the same on both sides of the wire. If it is not, equalize the distance by moving the outboard bearing slightly, as the case may require. Now turn crank around and bring pin up to the wire at the opposite center; again measure the distance from the wire to the inside of the collar or shoulder as before, which should be the same as at opposite end. If engine is fitted with locomotive guide bars, or a single bar-guide, the distance from the wire to the guide should be taken with the calipers at each end of the stroke, equalizing the distance of bar from wire by slightly moving the guides as the case may require. Should shaft be much out of line, requiring considerable movement of outboard bearing, it would be advisable to remove the quarter boxes and scrape them to an even bearing, otherwise the shaft in its new position will be liable to bear very heavily at the ends of the quarter boxes only and cause excessive heating. Replace all the parts removed and make the necessary adjustments with the crank on the dead center. Turn engine to opposite dead center and make such that the crank passes the dead center easily.

13. Engine Slipping with Heavy Train.—"If an eight-wheel engine was down on her back boxes would it have a tendency to make the engine slip with a heavy train?"

Answer.—An eight-wheel engine usually has about one-third of its weight supported by the engine truck and the other two-thirds supported on the drivers through the

medium of equalizers and springs. The truck supporting the weight at the front end is one point and the fulcrums for the equalizers on each side of the engine form the other two points, thus forming a tripod to distribute the weight equally on uneven track. The two back points of the support place the weight on the fulcrums of the equalizers and it is transmitted to the springs, saddles, and hangers for the purpose of lessening the shock and equalizing the load on rough track. It is evident that each end of the equalizer must support one-half of the load or weight at the fulcrum and when one end of the equalizer moves down the other end will move up an equal distance and the weight on the support is the same as if the equalizer was in a horizontal position. Therefore, an engine slightly low behind or down on her back boxes would not lose her adhesion or be more liable to slip providing the points of support were the same and the equalizer free to move on the fulcrum. If the load intended to be carried on the drivers was transferred to the back boxes on account of their being blocked between the top of the box and the frame, the equalizing feature would be destroyed and the forward wheels would support little of the weight, if any. More weight would be carried by the truck and the result would be less weight on the drivers, which would reduce the adhesion and cause the engine to slip.

14. Which Wheel Slips?—"The wheels of a locomotive are fixed fast on the axle. The outside rail of a curve being the longest, how do the outer and inner wheels keep even in rounding a curve? If either slip how much?"

Answer.—If we were to ask how much surface of the tire of a driving wheel of a locomotive comes in contact

with the rail, the answers from the various enginemen would vary. Some would claim that ½-inch and others 2 inches come in contact with the rail. Occasionally we would be informed that there was only a fine line or point of contact, which is correct. In order to get more than a point it would be necessary to have a flat spot on the tire equal to the surface of the tire in contact with the rail. Therefore, when the tire is round we have only a small point of contact. Locomotive tires are turned slightly conical from the flange to the edge of the tire, usually ¼-inch, that is, the small diameter of the tire would be ¼-inch less than the large diameter. If the point of contact between the tires on a pair of wheels and the rails were the same distance from each flange the diameter would be the same, the wheels would roll in a straight line. Then when the wheels strike a curve the flanges of the outside wheels are brought close to or against the ball of the rail, making the point of contact at the largest diameter of the tread, and the point of contact of the tire and the rail is on the smallest diameter of the inside wheel and the flange is farther away from the rail. For an example, we will take a pair of wheels with tires 60 inches in diameter on the larger diameter of the tread and 59¾ inches in the smaller diameter, and we have the wheel with the flange near the rail moving a distance of 188.496 inches each revolution and the wheel on the inside of the curve, or with the point of contact on its smaller diameter, with the flange away from the rail will move a distance of 187.7106 inches, or .7854 of an inch less distance each revolution of the wheel, due to the difference in the diameters of the wheels at the points of contact with the rails. As there are 5,280 feet in a mile and the 60-inch wheel would make 336 revolutions per

mile there would be a difference of 22 feet between the distance covered by the inside and outside driving wheels, providing the wheels came in contact with the rails as described above. The lateral motion or side play between the face of the hubs and the driving boxes will permit the flange on the outside of the curve to roll toward the rail where the diameter is larger.

15. Leaky Mud Rings in Winter and Summer.—"Why do mud rings leak worse in winter than in summer?"

Answer.—On account of the greater differences in temperature, causing greater expansion and contraction. If a wide firebox, it is often due to lack of proper lubrication of the expansion pads or braces, and the unequal expansion of the frame and boiler, producing a strain on the mud ring and throat sheets when the expansion pads are dry or not properly oiled.

16. Duties at Completion of Trip.—"At completion of trip, what is necessary?"

Answer.—A thorough inspection of the locomotive. The fire should be well burned down and sufficient water in the boiler to avoid the necessity of hostler working injector while on the pit or in the house. Look at the firebox, crown-sheet and flues, then begin your inspection when you strike the ground, and examine all parts of the engine and tender, going completely around. Look for losse nuts, wedge bolts, cracked leaves in springs, defects in spring hangers and in spring rigging; note the temperature of all journals and bearings, look for broken or lost cellar bolts in driving and engine truck boxes. Examine flanges of wheels, see if pilot is too low. Uncoupling levers, grab irons, etc., should receive inspection. Shut off feeds on guide cups, see that all cotter pins are in place,

and figure that the inspector or any one else can not find any defect that you have not located. Then write a report of the necessary work, so that the roundhouse men can readily locate and make needed repairs.

17. Steam Heat Regulating Valves.—"What would you do if you could not get steam to go through the Mason steam heat regulating valve, after coupling onto the train? Also the Gold steam heat regulating valve, and the Leslie steam heat regulating valve?"

Answer.—The regulating valves mentioned above, although differing in form, all work on the same general principle, the amount of steam admitted to the steam heat system being controlled by a spring acting on a diaphragm which in turn regulates the opening and closing of the main inlet valve. As a rule, in case steam will not flow through the valve as spoken of in the question, the trouble is due to the main valve being stuck down, and a slight tap with a block of wood will often serve to loosen it. Before doing anything to the valve, however, it would be well to see that the main throttle admitting steam to the regulating valve is open, and also that the hose or flexible connection between engine and tank is not frozen up.

With the Mason valve in case steam will not pass through it, turn the wheel at the top to the left so as to reduce the tension on the spring; if this will not start the steam through it, the probabilities are that the piston in the lower part of the valve is stuck, due to corrosion, mud, scale, etc. A smart tap on this lower projection with a block of wood will then cause the piston to move upward, and so open the main valve. After the flow of steam is started and the system filled on the train the desired pressure can be regulated by means of the wheel

on top of the valve in the usual manner. There is also a possibility with the Mason valve of the main spring breaking; in this case the small spring acting on the auxiliary valve, which is attached to the lower face of the diaphragm, would close this auxiliary valve and so entirely prevent the admission of steam to the lower part of the piston, and consequently the main steam valve would not be opened. A broken main spring is very rare, however, and can easily be detected by the "feel." In case of doubt, however, screw down on the regulator so as to unseat the auxiliary valve. If this will not start a flow of steam there is hardly any question but what the spring is broken. The only thing to do then is to remove the spring case, and, if you have no spring to apply, block the diaphragm down, regulating the pressure by means of the main throttle.

With the Gold regulating valve, if you have found the main throttle open and the connections not frozen up, so that you are confident the trouble is in the regulating valve, first slack off on the small handle which serves as a jam or lock nut, then screw down (turn to the right) on the main regulating valve handle. This will force the main steam valve down and open it. If, after screwing down as far as you can, you still find that steam will not pass through the valve, you will know that either the main adjusting spring or else the stem on the main steam valve is broken. In either case if you are where you can not get access to the various parts to make repairs, remove the spring case, which is the upper part of the valve, and block the main steam valve open, regulating the pressure with the throttle as above.

With the Leslie regulating valve, if confident that the trouble is in the valve, that is, if you know that the pipes

are not frozen and that the steam throttle is open, first screw down on the regulating valve (turn to the right) so as to put a tension on the main spring, and force the small auxiliary valve open. This will admit steam to the top of the main piston, which in turn will open the main steam valve. After screwing down on the regulating cap as far as it will go without any result, take a block of wood and strike the bottom nut or cap on the main body a smart blow; this will jar the main piston loose in case it should be stuck. If, however, this does not produce the desired result the probabilities are that either the main spring or the piston stem are broken; in this case the quickest remedy if time is short is to close the main steam throttle, then with a wrench remove the lower cap on the main valve body and take out the spring which holds main valve closed. Replace bottom cap. The main valve will now open by its own weight and steam will flow directly through the regulator. The pressure, of course, must be regulated by the steam throttle.

18. Area of Safety Valves.—"If a safety valve is 1/5 of the horsepower of a boiler (i. e. the area of the valve in square inches), and if a boiler is 30 horsepower, what would be the area of the safety valve in square inches?"

Answer.—According to the rule given above the area of the safety valve would be 6 square inches and therefore the diameter would be 2½ inches (2½ inches is the nearest standard size).

The rule given above is seldom used, as boiler horsepower is an indefinite quantity. Safety valves are usually proportioned in relation to grate area. As the safety valve is intended to relieve the boiler of excess steam, and as steam is generated by the fuel burned, it is plain

that the size of the grate largely governs the amount of fuel burned in a given time, and consequently the amount of steam generated. The grate is therefore the better basis on which to calculate the area of the safety valve, the simplest rule being that of the British Board of Trade, which requires that the safety valve have an area of one-half of one square inch for each square foot of grate area. Another rule adopted by the same body is:

$$\frac{37.5}{\text{Gross pressure}} = \text{sq. in. of safety valve per sq. ft. of grate.}$$

This calculation at low pressures is equal to using about 4/10 (.4) square inch of safety valve area to 1 square foot of grate area, which is almost double the requirements of the various Boards of Underwriters in the United States, but is nevertheless a very safe rule to follow.

19. Pressure Gauges.—"How are pressure gauges computed in proportion with a scale? I understand a gauge registers pound per volume, and a scale pound per weight. Is there a rule for figuring the tension of the spring of the gauge?"

Answer.—All pressure gauges register weight, not volume. That is, the pressure exerted on a gauge is the same as a weight on a scale, as the pressure of any fluid exerted on a certain area is equal to an equal weight resting on the same area. The graduations on the dial are not computed, but accurately graduated by means of an open mercury column. The pressure gauge is not operated by means of a coil spring, but by a flattened spring tube curved to a certain radius; the pressure entering this tube has a tendency to straighten it. As the tube is straightened a toothed sector attached to the free

end of the tube by means of a connecting arm rotates a small pinion mounted on the same shaft that carries the pointer or hand. The movement of this hand for each pound of pressure is determined by means of the mer-

Double Spring Locomotive Gauge.

cury column as noted above, and the dial marked accordingly. The cut herewith shows the internal construction of a modern double spring-tube gauge.

20. Steam and Air Gauges.—"Is there any difference in the construction of a steam and air gauge?"

Answer.—No material difference in general design; the steam gauge being intended for higher pressure is simply made heavier.

21. Angularity of Eccentric.—"In putting eccentrics on a new axle, what degree should the longest line be from the crank pin, in front and back motion, freight and passenger engine, and why?"

Answer.—The degree of angularity depends on the amount of outside lap of the valve, the lead desired, and whether it is an internal or external admission valve, direct or indirect motion, etc. In fact, there are many different factors governing the degree of angularity, so that no definite answer can be given to the question as above. In order to see this clearly, imagine an engine with valves having no lap and set without lead. In this case the eccentric would stand at right angles to the crank pin, or 90 degrees back of it if the go-ahead eccentric is considered, and the engine has outside admission valves. We will now add ¾-inch to the valve on each side for outside lap. Now in order to overcome this lap and have the port open just a line at the beginning of the stroke, it is necessary to turn the eccentric forward toward the pin. The angle will now be less than 90 degrees If you now desire to give the engine lead you must still further advance the eccentric, and so again change the angle. Again, if there was a difference in the lengths of the upper and lower arms of the rocker arm it would make a difference in the distance necessary to move the eccentric, and so again change the angle. Consequently you can see that the degree of angularity is subject to a wide variation.

22. Piston Speed.—"How do you find the piston speed in feet per minute when the number of miles per hour, the driving tire diameter and the stroke are known?"

Answer.—First find the circumference of the wheel by multiplying the diameter by 3.1416. If the diameter of the wheel is given in inches, either reduce the circumference found to feet or reduce the number of feet in a mile (5,280) to inches, then divide the circumference into

the number of feet (or inches, as the case may be, only be careful to divide feet into feet and inches into inches) per mile, which will give you the number of revolutions the wheel will make in going one mile. As the piston makes two strokes to every revolution of the driver, we must multiply the revolutions by 2 to get the number of piston strokes, and this by the length of the stroke in feet to get the number of feet traveled.

If the engine was making a mile a minute this would be your answer, but as the speed may be more or less than a mile a minute, or 60 miles per hour, we must find what proportion the actual speed is to 60 miles per hour and take that proportion of the answer, as above found for 60 miles per hour, as our piston speed. For instance, if the engine was running at the rate of 25 miles per hour this would be 25/60 of 60 miles per hour, or 5/12. Then 5/12 of the piston speed as found at the rate of a mile a minute would be the speed for 25 miles per hour. The following example will make it plain:

Find the piston speed of a locomotive having 56-inch driving wheels, 24-inch stroke and running at the rate of 18 miles per hour.

$56\times3.1416=175.9296$ inches. Call it 176 inches, as there is no use carrying out the small fractions. Now as 176 inches will not make an even number of feet, we reduce 5,280 feet in a mile to inches. $5{,}280\times12=63{,}360$ inches. To find revolutions per mile, divide 63,360 by 176. $63{,}360\div176=360$ revolutions per mile.

The piston makes two strokes in each revolution. Then $360\times2=720$ strokes per mile. As the stroke is 24 inches, or 2 feet, then the piston will travel $720\times2=1{,}440$ feet per mile. Now if the engine was running at

the rate of 60 miles per hour, or a mile a minute, the piston speed would be 1,440 feet per minute, but as the engine is running but 18 miles per hour, and as 18 is 18/60 or 3/10 of 60 miles per hour, then the piston speed would be 3/10 of 1,440 feet. 1/10 of 1,440=144, and 3/10=144×3=432 feet, or the piston speed at 18 miles per hour. The piston speed of the same engine at 20 miles per hour would be 20/60 or 1/3 of 1,440=480 feet per minute, and at 30 miles per hour 30/60 or ½ of 1,440, or 720 feet per minute, and so forth.

23. ENGINE RATING.—"Please explain fully the manner in which engines are rated, that is, what allowances are generally made for internal friction, given degrees of grade and curves, etc., after the tractive power has been figured out."

Answer.—The tractive power as found by calculation expresses the maximum power or effort put forth by the locomotive, and consequently means the pull the engine exerts at the rear drawbar. By means of the dynamometer car it has been determined definitely the number of pounds of tractive power necessary to overcome the resistance due to grade, to friction, to speed, etc. This is always expressed in pounds tractive power per ton, and while it varies to quite an extent due to condition of track, load per car, condition of cars, etc., yet we have been enabled by means of repeated tests to formulate a set of rules for calculating the various resistances, that give approximately close results.

The resistance on straight and level track due to friction varies from 5 to 10 pounds, but is usually taken as 7 pounds and we will therefore use that figure.

Resistance due to grade=rise in feet per mile× .3788, which is about equal to 20 pounds for each per

cent of grade. Resistance due to curve=½ pound for each degree of curvature. Resistance due to speed=$3+\frac{\text{Velocity}}{6}$. (Authorities differ on this factor of resistance; the one given is quoted from the Baldwin Locomotive Works. Colvin gives: Resistance due to speed=$\frac{\text{Square of Speed}}{171}+6$.)

Therefore knowing the tractive power of an engine, to find what the engine will pull add together the resistance due to friction, the resistance due to grade, the resistance due to curve, and the resistance due to speed, and divide this into the tractive power. From the result subtract the weight of the engine and tender in tons, the remainder will be the tonnage rating.

Example: How many tons can a locomotive of 30,000 pounds tractive power haul up a grade of 1 per cent with curves (not compensated) of 10 degrees at 10 miles per hour? Weight of engine and tender 100 tons.

We then have:

Friction resistance	= 7	pounds.
Grade resistance	=20	pounds.
Curve resistance	= 5	pounds.
Speed resistance	= 4.6	pounds.
Total	36.6	pounds.

30,000÷36.6=819, and 819 — 100=719 tons.

24. Combined By-pass Relief Valve.—"Please explain the combined by-pass and relief valves, sometimes called drifting valves, which are used on the valve chests of piston valve engines."

Answer.—There are quite a number of different types of by-pass relief valves used in connection with piston valves, one of the more common kind being simply a circular disc valve held in place by the steam chest pressure when working steam, and falling away from its seat by its own weight when steam is shut off and the engine is drifting. When the seat is uncovered it opens a port connecting the steam ports in the cylinder with the steam cavity in the steam chest, so the air compressed in one end of the cylinder can pass over into the other end.

One of the best by-pass valves in use is that used by the Pennsylvania Railroad, and consists of a small steam chest placed on top of the main steam chest. The ports leading from the small steam chests lead directly into the main steam ports; communication between the two ports, however, is cut off by means of a flat plate sliding on a hollow stud, the plate resting on and covering both ports. When the throttle is opened steam flows up through the hollow stud and fills a chamber above the flat plate, holding it firmly to its seat. When the throttle is closed, however, and the engine is drifting, there is nothing to hold the plate to the seat but its own weight; consequently the air compressed by the piston in its forward and backward strokes, passing up into the main steam ports, flows from these into the smaller steam ports leading into the small steam chest, and pressing against the underside of the flat plate raises it off its seat, so the compressed air can flow directly into the other end of the cylinder.

25. Holding Power of Cylinder Head Studs.—"If on a cylinder 22×28 inches having an area of cylinder head face of 380.1336 square inches, the head being

fastened to the cylinder by means of 17 studs, and the nuts on each stud being pulled to a tension of 5,000 pounds, or a total of 85,000 pounds for the 17 studs, if then by admitting steam at 200 pounds pressure, thereby producing a pressure of 200×380.1336 or 76,067.72 pounds total on the cylinder head, would there be any additional strain on the studs in holding the head to its seat, or would the steam pressure have to be greater per square inch so that it would exceed the 85,000 pounds before you would get any extra or additional strain on the studs?"

Answer.—The total tension on the studs would be increased in proportion to the pressure admitted to the cylinder, which in this case is 76,026 pounds. Therefore the tension or strain on each stud would be increased 76,026÷17=4,472 pounds, and all that prevents leakage therefore is the difference between the tension originally put on the studs with the wrench, which was 5,000 pounds, and the strain exerted by the steam, which is 4,472 pounds, or 5,000 — 4,472=528 pounds per stud.

26. Superheated Steam.—"First—Why does not the pressure of the superheated stem at the outlet of the superheater effect a backward current as well as a forward current and tend to establish, or until it has established, equalization of pressure between the steam chest and boiler? In other words, how does the boiler (lesser) pressure feed against the superheated (greater) steam pressure?

"It seems that this explodes the old theory of 'greater toward the lesser.' I have a lingering suspicion that it is owing to the momentum of the boiler steam which has a greater density. But what is your opinion?

"Second—What kind of lubricator is used; whether force feed or not; also the piping arrangements and its operation. This also seems as though it were 'lesser toward the greater.'"

Answer.—You are falling into the same error that many others have made on the superheated steam proposition. The universal opinion appears to be, among those who are unfamiliar with the subject, that superheating or increasing the temperature of the steam after it leaves the boiler, increases its pressure in a corresponding ratio. This does not obtain in actual practice, however, as superheating simply dries steam, forming it into a perfect gas. Although the temperature of the steam is raised in superheating from ninety to two hundred degrees, the pressure is not increased in the least. In fact, the only way in which the pressure of steam could be increased by superheating would be to inclose it in an absolutely tight box, and in this case the pressure would be raised but slightly. Therefore, your "lingering suspicion" is not correct. The steam in passing through the superheater from the boiler is simply dried and its temperature increased, and, consequently, it flows to the steam chest the same as saturated steam, the only difference being that superheated steam has been found to be what is called more "lively." In other words, it is more rapid in its flow.

"Replying to the second part of your question relative to lubricators, in a series of tests conducted with engines equipped with superheaters, it was found that the hydrostatic lubricator gave equally as good results as the force feed lubricator; in fact, on most roads it was preferred to the force feed, owing to the mechanism of the latter type of lubricator being somewhat complicated and

liable to fail. Since these experiments were conducted, however, a new type of force feed lubricator has been placed on the market which practically overcomes previous objections to this type. The piping arrangements with the original engines were practically the same as on engines not equipped with the superheater. It was found in practice, however, that better results were obtained by running an additional pipe into the cylinder so that oil was not only taken into the steam chest for the purpose of lubricating the valve, but also into the cylinder direct for the purpose of lubricating the cylinder and cylinder packing. It was also found that in using superheated steam it was necessary to use more oil than when using saturated steam."

27. Effect of Springs Settling on Steam Distribution.—"In a locomotive equipped with the Walschaert gear, where the foot of the link is not brought down in line with the piston rod, is not the steam distribution seriously disturbed by the settling of the springs after the valves are set, or the spring hangers or equalizers are changed?"

Answer.—There is a slight disturbance in a case of this kind, but not of sufficient moment to seriously affect the performance of the engine. This disturbance would obtain regardless of whether the link foot was originally extended down in line with the piston or not.

28. Effect of Increased Angularity of Main Crank.—"Would the increased angularity of the return crank of the Walschaert valve gear unduly affect the steam distribution if, regardless of the position of the link, the foot be extended, regardless of length, so that the return crank connection to this foot would be in line with the piston rod, and the return crank then given the

increased throw to compensate for the extra leverage necessary to give the valve full travel?"

Answer.—It would not, providing all other parts were carefully laid out and their movements plotted and the other parts then so designed as to overcome the distortion. There is no valve gear which lends itself so readily to changes in location of parts and general design without interfering with the steam distribution as the Walschaert.

29. Blow in Two-Cylinder Schenectady Compound.—"What causes the blow in a two-cylinder Schenectady cross compound locomotive when working simple, or when trying to start a train in simple position?"

Answer.—When all parts are in good order these engines will not blow when working simple. In the case mentioned we must assume that the engine only blows when working simple. This would indicate that either the high-pressure valve or cylinder packing was defective, as the blow from either of these defects is only noticeable when the engine is working simple with the separate exhaust valve open. When working compound the steam leaking by a defective high-pressure valve, or defective high-pressure cylinder packing, passes into the receiver and so into the low-pressure side and consequently is not noticed as a blow at the stack. The question is too indefinite for an exact answer.

30. Action of Two-Way Valve, Schenectady Two-Cylinder Cross Compound.—"What takes place in the intercepting valve when I place the two-way valve in compound position, and when I place it in simple position?"

Answer.—When the two-way valve in the cab (some-

times called three-way or emergency valve) is opened, steam, or compressed air, whichever medium is used, enters behind the separate exhaust valve, forcing it forward so that the exhaust from the high-pressure cylinder, instead of being trapped in the receiver, escapes by way of the separate exhaust. When the main throttle is now opened, steam entering behind the intercepting valve forces it forward so as to open a direct passage from the live steam pipe direct to the low-pressure cylinder. Now as the separate exhaust is held open by the steam or air from the two-way cock in the cab, it will not allow the pressure to accumulate in the receiver and so force the intercepting valve shut, therefore the engine will continue to work simple until the two-way valve is closed. As soon as the two-way valve is again closed or placed in compound position the spring attached to, and acting on, the separate exhaust valve pulls it back into the closed position. As the exhaust from the high-pressure cylinder can not now escape from the receiver by way of the separate exhaust as before, it will naturally bank up in the receiver until the pressure is raised high enough to force the intercepting valve back into its original position, thus shutting off the supply of live steam to the low-pressure cylinder and allowing the receiver steam to take its place, thereby causing the engine to work compound.

31. Direct and Indirect Engine.—"I would like to have a good definition of a direct and an indirect motion engine. Is an engine of the following description a direct or an indirect motion engine? Inside admission valves, single rocker arm, and eccentrics on the same side of the journal as the main pin. One engineer says it is di-

rect by the rocker arm and indirect by the valve and eccentric."

Answer.—A direct motion engine is one in which the motion of the eccentric is imparted direct to the valve, that is, when the eccentric is moving forward the valve moves forward, and when the eccentric moves back the valve moves back, or, in other words, an engine in which the motion imparted to the valve by the eccentric, through the link, is not reversed by means of a rocker arm. An indirect engine is one in which this motion is reversed.

The engine referred to in the question is a direct motion engine, as with the eccentric in the position shown and a single rocker the valve moves forward with the eccentric. The following diagrams should make the matter perfectly clear:

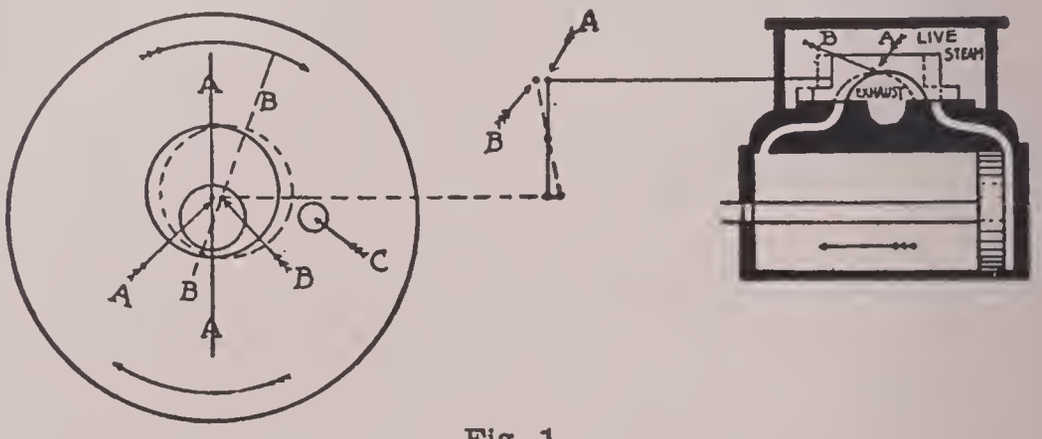


Fig. 1.

Fig. 1 shows a main driving wheel with crank pin *C* on forward center. There is also shown a section through the cylinder and steam chest of an engine with an ordinary slide valve. The link is not shown, as it does not enter into the problem of direct or indirect valve motion. In the figure the cylinder and valve are intentionally drawn large (out of proportion to the wheel), in order to make the explanation more clear.

Referring to the figure, it will be seen that the piston is at the front end of the cylinder, and the wheel revolving forward. The full lines show the position of the valve in the center of the seat, and also the position the eccentric and rocker arm would take with the valve in this position. It will be seen, however, that if we left the valve, eccentric, etc., in the position shown no steam would be admitted to the cylinder, as the lap of the valve covers the steam port. Therefore, in order to overcome the lap and also to give the engine the desired lead, we must shift the valve back. As the valve is connected to, and its movement governed by, the eccentric, however, it is plain that if we desire to move the valve we must move the eccentric first. By looking at the figure it is seen that in order to start the piston back we must open the front steam port so as to admit steam ahead of the piston. Therefore, in order to open the front steam port it will be necessary to pull the valve back. The problem is now, which way shall we move the eccentric to accomplish this? If we had no rocker arm, that is, if the eccentric was connected straight or direct to the valve, you might at first glance say: "Move the eccentric back." This would overcome the lap and give the engine the required lead in its present position. All right, but, as the wheel began to revolve it would carry the eccentric forward, which, in turn, would move the valve forward, and so close the port instead of opening it. We can therefore see that this will not do. We must shift the eccentric in such a manner that it will not only overcome the valve lap and give us a slight port opening at the beginning of the stroke, but also that it will continue to open the port as the wheel rolls forward. This we see can best be accomplished by the intervention of a

rocker, with the eccentric blade coupled to its lower end and the valve stem connected to the upper end. The wheel in rolling forward and carrying the eccentric with it causes the eccentric to push the lower end of the rocker arm forward, throwing the upper end back, thereby pulling the valve back until the wheel in its revolution has carried the eccentric to the point where its center passes the center line of motion, from which point the motion is reversed and the valve again moved forward until the back port is opened, and so on until the wheel completes a full revolution. It will thus be seen that while the eccentric is traveling forward the valve is traveling back, and when the eccentric is traveling back the valve is traveling forward; in other words, the valve and eccentric travel in opposite directions, making what is termed an indirect motion.

By reference to Fig. 1 it will be seen that there is one other way to pull the valve back sufficient to overcome the lap and lead, and also to continue to open the port as the wheel revolves, and that is to convert the engine into a direct motion engine by eliminating the rocker arm and moving the eccentric to a position below or ahead of the crank pin. The objection to this method, however, is that it would give us what is termed crossed blades, that is, the go ahead or forward eccentric being below the crank pin and the back up eccentric being above the pin, and as the forward eccentric blade is coupled to the top of the link and the back up eccentric blade is coupled to the bottom of the link, you can readily see that the blades would be crossed. The objections to the crossed blades are that as the lever was hooked up, and cut-off shortened, the lead would be decreased instead of increased as is desired in short cut-off.

Referring now to Fig. 2, which represents the same plan as Fig. 1, except we have now in place of the ordinary slide valve substituted an inside admission piston valve. The full lines, as in Fig. 1, show the position of the valve, eccentric and rocker arm with the valve in the center of the seat. We now see, however, that if we wish to open the front steam port in order to force the piston back we must push the valve forward, instead of pulling it back as in Fig. 1 (do not forget that this is an inside admission valve, while the other was outside ad-

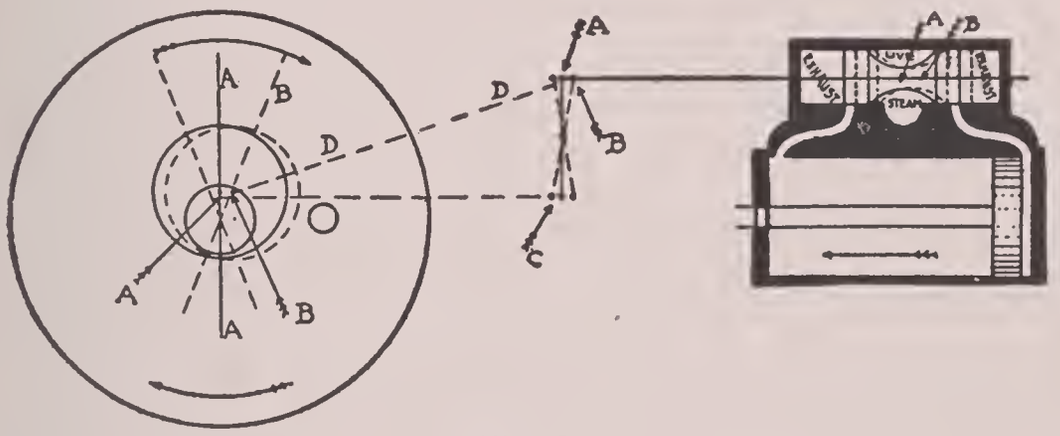


Fig. 2.

mission). We will, just for illustration, assume that we have changed nothing on our engine as found in Fig. 1 except the valve, which we changed from an outside admission slide valve to an inside admission piston valve. We still retain the rocker arm and connections as in Fig. 1. Setting the eccentric as in Fig. 1, let us now see what will be the effect on the valve. We notice the lower end of the rocker arm is pushed forward and the upper end, and with it the valve, is pulled back, opening the forward steam port to the exhaust and the back steam port to the live steam, by the amount of the lead, which is exactly opposite of what is desired. We now try throwing the

eccentric back the amount of lap and lead, still retaining the rocker. This we find pulls the lower end of the rocker back, as shown at *C,* and throws the upper end forward, as shown at *B.* It also carries the valve forward with it, as shown by dotted lines at *B.* We find that the valve has now been moved forward the correct amount to overcome the lap and lead, but upon revolving the wheel we find we are in exactly the same fix as in Fig. 1, that is, that as the wheel rolled forward the valve will be pulled back again and the port closed instead of opened. We now notice, however, that if we eliminate the rocker (that is, as a double rocker) entirely, and couple the eccentric blade direct to the valve rod, as shown by dotted line *D-D,* we not only overcome the lap and lead as desired at the beginning of the stroke, but also as the wheel revolves the port continues to open as desired until the eccentric center passes the center line of motion, as in Fig. 1, when the motion is reversed and the port closed.

We now see that by this method of connecting the eccentric and valve, when the eccentric is moving forward the valve is likewise pushed forward, and when the eccentric starts back the valve also moves back, or in other words, both move in the same direction, constituting what is termed a direct motion. In this figure, same as in Fig. 1, the same valve movement could have been obtained by retaining the rocker and moving the eccentric ahead of the crank pin. This would have made it an indirect engine, but would also have necessitated crossed eccentric rods, which, as explained above, are undesirable.

From the foregoing it is plain that the style of valve or location of eccentric have nothing to do with the direct

or indirect feature of the motion. This depends entirely on the rocker arm. Therefore an engine having a double rocker arm, that is, a rocker with one arm above and the other below a common center, and having the link or transmission bar coupled to the lower end and the valve stem to the upper end of the rocker, is bound to be an indirect motion engine, as the rocker arm reverses the motion of the eccentric, while an engine having a single rocker, or one on which both arms either stand up or hang down, must be a direct motion engine, as the eccentric motion is imparted direct.

THE FOLLOWING QUESTIONS PERTAIN TO STATIONARY PRACTICE.

32. Connecting a Water Column.—"How would you connect a water column to a boiler?"

Answer.—With an internally fired boiler, that is, a boiler having a firebox enclosed by the boiler, the upper end of the water column should be connected to the highest point of the steam space, or steam chamber of the boiler proper. You understand, of course, that if the boiler is fitted with a steam dome, or steam drum, that the water column is not to be connected to this, but only the highest point of the boiler proper. The lower end of the water column on a boiler of this type is to be connected so that the opening is from 2 to 4½ inches above the crown sheet. The exact distance is optional, the intention being simply to assure having water above the crown sheet so long as there is water in the water column. With externally fired and water tube boilers, the upper end of the water column is connected as before to the highest point of the boiler proper, while the lower end of the column must not be tapped into the boiler at any point that is lower than the highest point through which the heat passes (as in a return flue boiler the highest flues), or lower than the highest circulating tubes in a water tube boiler.

The connections can be made either with pipe or hydraulic tubing of sufficient strength or can be connected direct by means of suitable flanged unions or connections.

33. Water Level.—"How would you find the water level?"

Answer.—First see that your boiler is properly set and leveled; the water level is then determined, being governed by the type of boiler, service, etc. Thus in a stationary boiler it is not necessary to go more than 2 or 3 inches above the highest point of the boiler exposed directly to the action of the fire for the lowest water level, while in a steamboat boiler that is being continually thrown out of its normal position by the tossing of the boat, a little greater margin is desired.

34. Connection of Pump.—"How would you connect the pump to the heater and boiler?"

Answer.—When the heater consists of a combined heater and filter the intake of the pump is usually connected near the lower end of the heater, say about 12 or 18 inches from the bottom. Where the heater is not of the combined type the pump suction is connected at a higher point so as to obtain water that has been thoroughly heated, and also get above the sediment deposited. The discharge end of the pump is connected to the boiler at the end farthest removed from the firing end and preferably as high up on the boiler as possible, as it has been found that a high feed water connection is an aid in boiler preservation, fuel economy, etc., by giving a better and more rapid circulation.

35. Valves.—"What is the difference between a slide valve, balanced valve, and a piston valve?"

Answer.—What is usually termed the slide, or D valve, is a valve of the ordinary rectangular type having the exhaust cavity in the center of the under side of the valve. In a valve of this type the steam chest pressure

acts directly on the top of the valve, thereby increasing the friction between the valve and its seat. The balanced valve is of the same general shape as the common slide valve, but in this type of valve provision is made to relieve the top of the valve of a greater part of the pressure by enclosing a part of the top of the valve by means of strips let into grooves or slots cut into the top of the valve, these strips being supported by means of springs, and are thus held up against a plate, known as the pressure or balance plate and bolted to the steam chest cover. These strips held up to the pressure plate form a steam-tight joint, so as to virtually enclose the greater part of the top of the valve against pressure, or so that no pressure can act directly upon it. The leakage is taken care of by means of a hole through the top of the valve, which is always in register with the exhaust cavity in the valve seat. There are other forms of balanced slide valves in use, one of the best known having one or more circular discs bolted or cast to the top of the valve, the disc being enclosed by a beveled spring ring which forms a steam-tight joint against the balance or pressure plate.

The piston valve is so called in that its form is that of two piston heads joined by a reduced center. A common thread spool is the best illustration of the ordinary piston valve. The piston valve is enclosed in a circular bushing or housing which forms what is termed the valve seat. Some piston valves are simply straight plugs having water grooves cut around their outer circumference to make them steam tight, while others (the majority) have snap packing rings fitted in grooves to prevent steam leakage. Piston valves are either inside or outside admission type, and as the direct pressure only acts against the ends of the valve, and the area of the ends

being equal, this type naturally becomes a perfectly balanced valve.

36. Fitting Brasses.—"What is the proper way to fit the brass to the crank pin?"

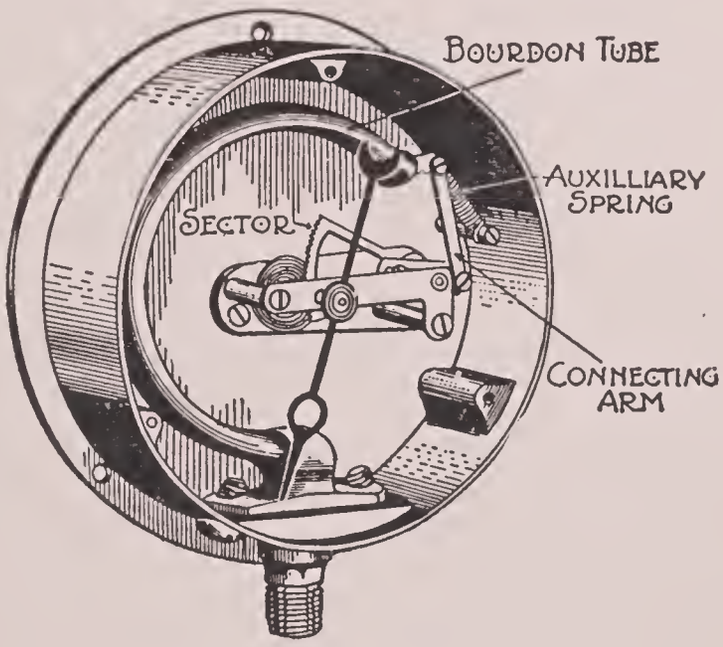
Answer.—It depends largely on the type of engine, as on that type of engine known as the self-oiling type—where the crank dips into a vat of oil at each stroke—the brasses should be left open a sufficient amount to allow the oil to get to all parts of the bearings, while on the other types of engines where the pin is lubricated either by means of an oil cup attached directly to the rod strap, or is oiled centrally through a proper oil hole drilled into the center of the pin, the brasses should be fitted up so as to key brass to brass. In both cases, however, the brasses should be given a full crown bearing only, being slightly relieved at the top and bottom to prevent any possible pinching action when keying up. Where the rod alignment is constant, as in stationary practice, very little lateral play is necessary. Where the alignment is inclined to be shifted to either side of a common center, however, as in a locomotive, lateral play must be provided for, the amount depending on the length of the connecting rods.

37. Steam Gauge.—"Explain the working of the steam gauge."

Answer.—The steam gauge consists of a device for registering the steam pressure in a boiler. The principal feature of the modern gauge is a slightly flattened bent tube, known as a Bourdon tube, the lower end being open to boiler pressure, and the upper or free end being closed or sealed. This tube should be connected to the boiler by means of a curved or syphon pipe in order to keep the Bourdon tube filled with water and to prevent

it being raised to a very high temperature, as if steam is admitted direct to the Bourdon tube the accuracy of the instrument is considerably impaired. The upper or free end of the tube is connected by an arm to a toothed sector which meshes into a small pinion mounted on a shaft to which the index hand is fastened. The action of the gauge is as follows: The pressure of the steam in the boiler acting on the water in the bent tube has a tendency to cause the tube to straighten, this straightening process being in proportion to the pressure exerted. As the tube is straightened the arm attached to the free end causes the toothed sector to move, which in turn causes a rotation of the small pinion with a corresponding movement of the hand or pointer, the hand pointing to the figures on the dial indicating the amount of pressure exerted. The gauge and parts are so designed that a very small change in the curvature of the Bourdon tube is multiplied so as to be easily observable on the face of the dial over which the pointer moves. On modern steam gauges a small coil spring is attached to the body of the gauge and to the free end of the tube to assist in bringing the tube back to its normal position, and so prevent the tube from taking a permanent set, which would eventually obtain due to the constant movement of the tube with each change of pressure. There was formerly in use a steam gauge in which the sector rested on a brass diaphragm which moved up and down with each change of pressure, the pressure being recorded in the usual manner by means of a pointer and numbered dial. This form of gauge was very unreliable, however, and was discarded with the discovery of the Bourdon tube. Since the introduction of the Bourdon tube gauge, however, the exponents of the diaphragm gauge have made further

experiments and improvements until at last they have perfected a gauge, termed the capsular spring gauge, which consists of two corrugated diaphragms rigidly locked together, there being an upper and a lower diaphragm, the steam entering between them, so that what was formerly with the old style single diaphragm but a straight movement, is now doubled. This form of gauge is highly commended, it being claimed that all vibration of the pointer frequently noticed on gauges fitted with the Bourdon tubes, and due to the vibration of this tube, is entirely eliminated by the capsular spring box.



Steam Gauge.

38. SAFETY VALVE.—"Explain the working of the safety valve."

Answer.—The safety valve consists of a valve screwed into an opening in the steam space of a boiler, and arranged to open at a predetermined pressure for which it has been set, this in order to relieve the boiler of any ex-

cess pressure and so prevent an explosion. It is usually placed on the highest point of the boiler in order that any floating sediment or foam may not be carried into it when the pop is open and so impair its efficiency. In general it consists of a case with a circular opening having a conical seat on which a valve fits accurately, and is held in place by a spiral spring, or by a lever, which in turn is held by a spring or by movable weights. The lever and weight type of safety valve is little used now, however, the spring actuated safety valve being the one in general use. The action of the safety valve is as follows:

The spring is screwed down to a certain tension by means of an adjusting nut; when the accumulated pressure in the boiler acting against the lower area of the valve is sufficient to overcome the tension of the spring the valve is raised, and steam escapes around it until the pressure is again reduced to a point less than the tension of the spring, whereupon the spring again forces the valve to its seat. The tension on the spring, and consequently the pressure at which the valve opens and closes, can be increased or decreased by screwing down or up on the adjusting nut. With the old style lever actuated safety valve, the pressure at which the valve opened was regulated by sliding the weight on the lever to or from the fulcrum. Sliding it toward the fulcrum would decrease the pressure, and sliding it away from the fulcrum or toward the end of the lever would increase the pressure necessary to open the valve. The modern type of safety valve is frequently fitted with a muffling device in order to lessen the noise. It is also fitted with an adjusting ring which regulates the height of the opening between the valve and its seat, and by

means of this regulating ring the valve can be very finely adjusted.

39. Lap of Valves.—"What is the inside and outside lap on valves for?"

Answer.—Valves are given inside lap in order to delay the exhaust and so get a little more work out of the steam. Inside lap can only be used to an advantage, however, on engines having a slow piston travel, as otherwise the delay to the exhaust would result in excessive compression and the loss in work would be greater than the gain. Outside lap is given the valve in order to permit of the steam being worked expansively, as you can readily see that if the valve had no outside lap the steam port at one or the other end of the cylinder would be always open except at the end of the stroke.

40. Piston Clearance.—"Explain how to find the clearance between the piston head and the cylinder head."

Answer.—If the piston is coupled to the crosshead, disconnect the main rod and push the piston forward until the piston head strikes the front cylinder head; now scribe a mark on the guides showing the extreme forward travel of the crosshead. After you have scribed this mark, pull the piston back until the piston head strikes the back cylinder head and scribe a mark on the guides as before. These marks are what are termed striking points, and are usually scribed deep enough to be used as a permanent reference. With the crosshead in the extreme back end, measure the distance from the forward face of the crosshead to the front striking point. The difference between the distance so found and the stroke of the piston is the total piston clearance. This clearance should now be divided so as to have an equal

amount at each end of the cylinder; this is done by lengthening or shortening the main rod.

41. First Duties in Taking Charge.—"What would you do first in taking charge of a steam plant?"

Answer.—The first thing to do would be to see if the boilers are in condition to carry the pressure at which the safety valves are adjusted. If the plant is an old one a very careful inspection would be necessary; if a new one, the builder's guarantee should be the limit of allowable pressure. The next thing is to see that the steam and water gauges are in perfect working order and properly connected. Do not have a steam gauge or upper end of a water column connected to a small or medium sized steam pipe from which there is a constant drain, as the pressure in such a pipe varies and is therefore unreliable. See that the safety valves are in good order and of dimensions sufficient to relieve the boiler. If the steam plant consists of two or more boilers, have a safety valve on each. See that your water supply is ample, and that the pumps and injectors are in working order. Do not depend on one pump or one injector, as either may fail at a critical time. See that your boilers are so set that any sediment will naturally gravitate toward the blow-off cock and not leave a mud pocket that is liable to cause a mud burn. See that ample facilities are provided for washing and taking proper care of the boilers. See that all steam pipes leading from the boiler are properly lagged and covered, as an uncovered pipe is simply an additional drain on the boiler from which no returns are received, besides wasting both coal and energy. See that ample provision is made for the admission of air through the fire to aid combustion, and that proper means in the form of stack dampers, etc., are

provided to retard or check combustion as desired. See that your facilities for receiving coal and removing cinders are such as to entail the least amount of labor, and last, but not least, see that all corners in the boiler room are cleaned out and no inflammable material left scattered about that would be liable to cause fires.

BOILER INSPECTION.*

"There is nothing more important about a steam plant, be it stationary type, as exemplified in the stationary power house, marine type, as in steamboats, or locomotive, as in the well-known locomotive engine, than the boiler, as the boiler can truly be said to be the heart of the plant from which energy in the form of steam flows to the various parts, there to be converted into power, etc. Given a good boiler, and there is no question but what the balance of the plant can be made to perform with a fairly satisfactory degree of efficiency, but if the boiler be defective, leaky, undersized, of poor design, weak, or in any way unfitted for the work it is called upon to perform or the energy it is supposed to produce, the balance of the plant, i. e., engines, dynamos, air compressors, etc., no matter how efficient in themselves, can not properly perform their allotted functions. Of what benefit is a well-designed valve gear or a set of good tight cylinders if you have no steam?

"In spite of all this, however, there is no part of a power generating plant, be it movable, as in the locomotive, or stationary, that receives less attention in comparison to its importance and the work it is expected to perform. Why is this? Simply because the boiler room has not an inlaid mosaic tile, or oiled and polished floor like the engine or dynamo room, neither has the boiler that attractive appearance that brass and polished bright

*F. P. Roesch, Courtesy "Locomotive Firemen and Enginemen's Magazine."

work lends to the engine or generator. However, a clean, well-kept boiler room will go far toward keeping up in an efficient condition a battery of boilers. Consequently, in preparing to make an inspection of a boiler plant the general appearance as regards cleanliness should be the first thing to observe. The appearance of the boiler room can as a rule be taken as a fair criterion of the condition of the boilers.

"Taking up, now, the list of questions, we will proceed to answer and explain them in their regular order as given:

Maker?—In preparing or filling out the regular form covering boiler inspections it is always advisable to give the name of the maker, if obtainable. First, because the names of most prominent boiler manufacturers are in themselves a guarantee of first-class, efficient workmanship, and, second, because it is possible to obtain from them blue prints covering the bracing, etc., of inaccessible parts of the boiler, together with such other information relative to material, etc., as may be desired.

Age?—The age of a boiler is important in that it gives us a very good idea as to the nature of the material used in its construction, as the use of steel has been comparatively recent. So far as the actual condition of the boiler is concerned, the treatment the boiler has received, the character of the feed water, etc., may have had a greater deteriorating effect than age itself. Where good treatment and good water have obtained, however, the age of the boiler must be taken into consideration, as the tensile strength of iron or steel subjected to constant heat and tension gradually decreases. The exact ratio of decrease in tensile strength has, however, not been definitely determined, some authorities recommending a

decrease of one-half of one per cent in pressure for each year of service, to compensate for the decrease in tensile strength; a better rule, however, would be to calculate the bursting pressure of the boiler by the regular formula and deduct from the original strength of the material one-half of one per cent for each year the boiler has been in service.

From Whom Was Boiler Bought?—This information wanted principally as a matter of record.

Address?—This answer is obviously for the same reason as above.

Flush or Overhanging Front or With Breeching?—This information applies more to the description, although signs of corrosion should be looked for.

Give Detail of Boiler Supports?—This is very important, and is something that must receive careful attention, as frequently boilers are so supported as to throw an undue and unnatural strain on the lower part of the seams; this applies especially to extremely long boilers whose diameters are out of proportion to length. With boilers of this type, supported on the ends only, cracks are very liable to develop at the circumferential seams. The approved methods of supporting ordinary cylindrical boilers is by means of lugs or brackets riveted to the boiler, resting on the brick wall in which the boiler is encased, or the boiler can be suspended from a suitable arch support by means of hangers. The practice of allowing boilers to rest direct on brick work should not be encouraged. Care must also be exercised to see that the boiler is so set that if it has any dip whatever, the dip will be toward the blow-off cock end and away from the furnace end in order to prevent the accumulation of mud or sediment immediately over the fire, where it is

very liable to cause blistering. No lime should ever be used in the construction of any walls, arches, midfeathers, etc., where it is liable to come in contact with the boiler; the brickwork should be set in fire-clay only. The setting should also be so constructed as to permit of a thorough examination of all external parts.

Is Boiler Set in Brick?—As stated above, if boiler is set in brick it must be properly supported and only fire-clay used as mortar.

Covered on Top?—Boilers are generally bricked over to prevent radiation of heat. This brickwork, however, should be so applied as to allow a thorough inspection of all seams and joints; if not, the brick should be removed in order to make the inspection, if for any cause, such as age, poor setting or general evidence of neglect, you are in any doubt whatever as to their condition. The biggest rule in the time card will apply equally as well in boiler inspection, viz.: "In case of doubt take the safe side and run no risk."

Is All Brickwork in Good Condition?—Where a boiler is all bricked in and likewise covered, you should be careful to see that the brickwork is in good condition, with no air holes in it, as these air holes through the brickwork not only decrease the efficiency of the covering as an insulating medium, but are liable to cause injury to the boiler through distortion of the plates due to uneven heating and cooling. Defective brickwork in a bridge wall is also liable to so deflect the flame from the furnace as to cause blistering.

Diameter of Boiler?—Take outside diameter accurately, as it is one of the important factors entering into the rule for calculating the safe working pressure.

Length?—Take length over all.

Diameter of Dome?—Same rule as diameter of boiler.

Height of Dome?—Storage for dry steam where no steam drum is provided.

Diameter and Length of Steam Drum?—These dimensions must be obtained, together with thickness of plates, bracing, general construction, etc., so that its strength can be calculated. The maxim, "A chain is as strong as its weakest link," will also apply to boilers and their fittings by paraphrasing it to read, "A boiler is as strong as its weakest part." The steam drum is an absolute necessity on many boilers, as it forms the only available space for the storage of dry steam from which the engine can draw its supply. Were it not for this steam storage reservoir, too much water would be carried over into the engine, thus causing damage to the machinery and also causing a severe pulsation or hammering in the boiler which would soon have the effect of starting seams and joints leaking.

Thickness of Shell Plates?—Take the thickness of the thinnest plate, and where the boiler has become eroded, corroded, pitted or grooved so as to make the ordinary method of measurement at the seam doubtful, have a hole drilled through at what you consider the weakest place and measure the thickness through the hole. This hole can then be plugged up, unless the weak part of the boiler is confined to but a small spot, in which case the spot can be cut out and an inside patch applied. Inside patches are preferable as they will not form mud traps or pockets same as an outside patch.

Thickness of Main Heads, Dome or Drum Heads, Dome or Drum Sheets?—Handle same as for shell plates as explained above and for the same reasons.

Brand on Shell, Dome or Drum Heads, or Sheets?—

All reputable manufacturers brand their products, some brands showing only whether iron or steel, others also stamping tensile strength, elongation, elastic limit, etc. In the former case a certified statement is given with each sheet of boiler plate sold by the plate manufacturers to the boiler builders, showing the above information, in which case the sheets are numbered and a record kept showing where, when, and to what boiler applied. So much importance is placed on the proper stamping or marking of plates entering into boiler construction by the government that the following law has been passed to cover fraudulent stamping, viz., Section 4432 of the laws governing the steamboat inspection service, as follows:

"Every person who counterfeits or causes to be counterfeited any of the marks or stamps prescribed for boiler-iron or steel plates or who designedly stamps, or causes to be stamped falsely, any such plates; and every person who stamps or marks or causes to be stamped or marked any such iron or steel plates with the name or trade mark of another, with the intent to mislead or deceive, shall be fined two thousand dollars, one-half for the use of the informer, and may, in addition thereto, at the discretion of the court, be imprisoned not exceeding two years."

Where plates are not stamped and no record of manufacturer can be found, a low tensile strength, elastic limit, etc., should be taken as the basis of calculation in figuring the pressure to be carried, and even then use a factor of safety of six. "Better be safe than sorry."

Iron or Steel Plate?—This can be determined by the stamping, or in the absence of stamp or mark, by the usual chisel test, or by external appearance.

Iron or Steel Rivets?—If no marks to identify, a small chip cut out of the head will enable you to determine.

Lap or Butt Joint?—Lap joints are those where the two plates to be riveted overlap one another. They are riveted with one, two, or three rows of rivets. It is the cheapest joint, but also the weakest. As applied to longitudinal seams the average efficiency of a single riveted lap joint is equal to about 55 per cent of the strength of the plate, of a double riveted lap joint to 70 per cent of the plate, and a triple riveted lap joint to 76 per cent of the plate, while that of a triple riveted butt joint is equal to 86 per cent of the plate, and in the diamond welt strip butt seam, as used by the Baldwin Locomotive Works on high-pressure locomotive boilers, an efficiency of 90 per cent has been obtained. On small and low-pressure boilers lap seams are commonly used, while butt seams are used on large and high-pressure boilers, for longitudinal seams; the circumferential seams on both types of boilers, however, are usually of the lap type. Figs. 1, 2, 3, 4, 5, 6 and 7 show different forms of riveted joints.

Double or Single Butt Straps?—This refers to the straps overlapping the joint. If but one strap is used either inside or outside it is called a single strap joint. Where two straps are used it is a double strap joint. See Fig. 7 showing double straps. This is the most efficient joint, as the rivets are in double shear.

Number of Rows of Rivets Each Side of Joint?—The strength of the joint depends in a large measure on the number of rows of rivets, up to a certain limit.

Number of Rows of Rivets in Lap Joint?—Seldom more than three rows are used, except in circumferen-

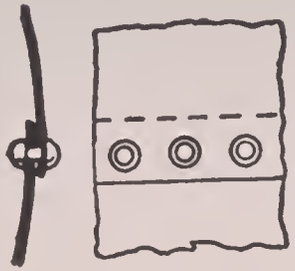


Fig. 1. Single Riveted Lap Joint

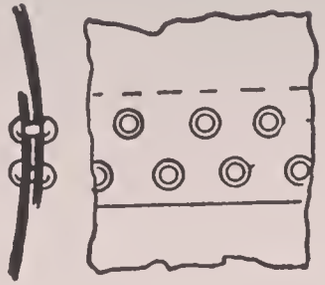


Fig. 2. Double Staggered Riveted Lap Joint

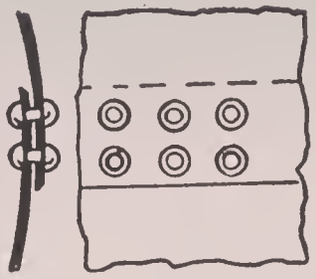


Fig. 3. Double Chain Riveted Lap Joint

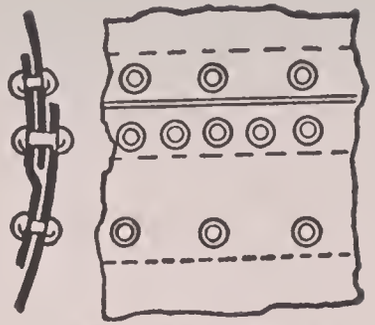


Fig. 4. Single Riveted Lap Joint with Inside Cover Plate

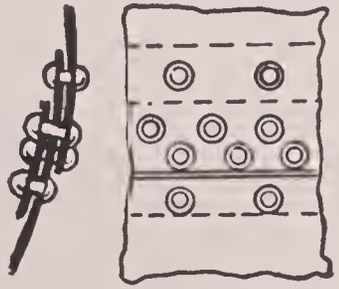


Fig. 5. Double Riveted Lap Joint with Inside Cover Plate

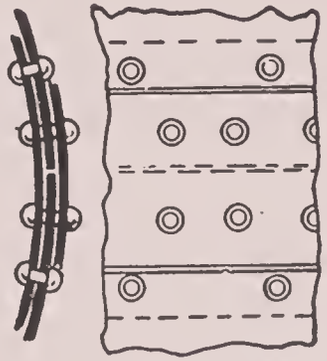


Fig. 6. Double Riveted Butt Joint

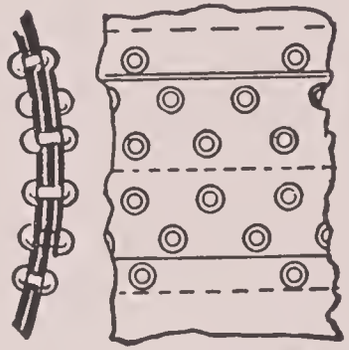


Fig. 7. Triple Riveted Butt Joint

Fig. 8. Rivet in Single Shear

Fig. 9. Rivet in Double Shear

tial seams of high-pressure boilers, in which four rows are sometimes used.

Number of Rows of Rivets in Single Shear?—Where a rivet passes through but two plates it is spoken of as in single shear; where it passes through three plates it is spoken of as in double shear (see Figs. 8 and 9). A committee appointed by the Master Steam Boiler Makers' Association to determine the relative value of rivets in single and double shear reported back as follows: "Shearing strength equals: For iron rivets, single shear, average per square inch, 40,000 pounds. Iron rivets, double shear, average per square inch, 78,000 pounds. Steel rivets, single shear, average per square inch, 49,000 pounds. Steel rivets, double shear, average per square inch, 84,000 pounds, this for riveted plates. It will be noticed that placing an iron rivet in double shear increases its shearing strength nearly 90 per cent."

Number of Rows of Rivets in Double Shear?—See answer to previous question and Fig. 9.

Pitch of Rivets in Single Shear? Pitch of Rivets in Double Shear?—The pitch of a rivet, whether in single or double shear, is the distance from center to center measured parallel with the seam. In many seams, however, one row of rivets may be in single while the other two or more rows are in double shear (see Figs. 4, 5, 6 and 7), hence the two questions.

Diameter of Rivet Hole in Shell?—The only way to obtain the size of rivet holes is to knock out a rivet. As the boiler should be carefully inspected for loose rivets, which, when found, should be replaced, there is no question but what the size of the rivet hole can be found without the necessity of knocking out a tight rivet. When knocking out a rivet look carefully for evidence

of shearing. This, if found, will be a good indication that the boiler at some time has been unduly strained.

Diameter of Rivet Hole in Dome or Drum Sheet?—See answer to question above.

Number of Rows of Rivets in Dome or Drum Sheet? Pitch of Rivets in Dome or Drum Sheet?—See answer to question relative to number and pitch of rivets in shell.

Is Dome Flange Single or Double Riveted to Shell?—The dome flange is the lower part of the dome where it is joined to the shell of the boiler. In large domes and high-pressure boilers they are usually double, and even triple, riveted, the number of rows of rivets necessary being based on the inside area of the dome cap, and the pressure exerted in an upward direction having a tendency to lift the dome off the shell. In large diameter domes braces should be used in addition to the riveted joint.

Thickness of Headers? Cast Iron, Cast Steel or Wrought?—This information can of course be obtained by direct inspection. See that heads, if of cast iron, are of ample thickness and show no signs of cracks. The cracks, if any, would be more noticeable on the under or inner side of the head.

Internal or External Furnace?—Internal furnace is contained within the boiler either wholly or in part. External is where the boiler sets over the furnace. In this case the furnace is not a part of the boiler, as a rule.

If Internal, Length and Width, Diameter?—Outside measurements.

Corrugated Furnace, Diameter, Thickness?—There are two types of corrugated furnace, the better known being the Morrison furnace, Fig. 10, having annular

corrugations, and the spirally corrugated furnace, in which the corrugations run in a spiral form, the object being to obtain greater longitudinal strength than obtains with the annular corrugations. Corrugated furnaces are much stronger to resist collapsing pressure than a plain furnace tube; are considerably more elastic, and have about 20 per cent more heating surface in the same length and diameter. In measuring the diameter, the greatest outside diameter should be taken.

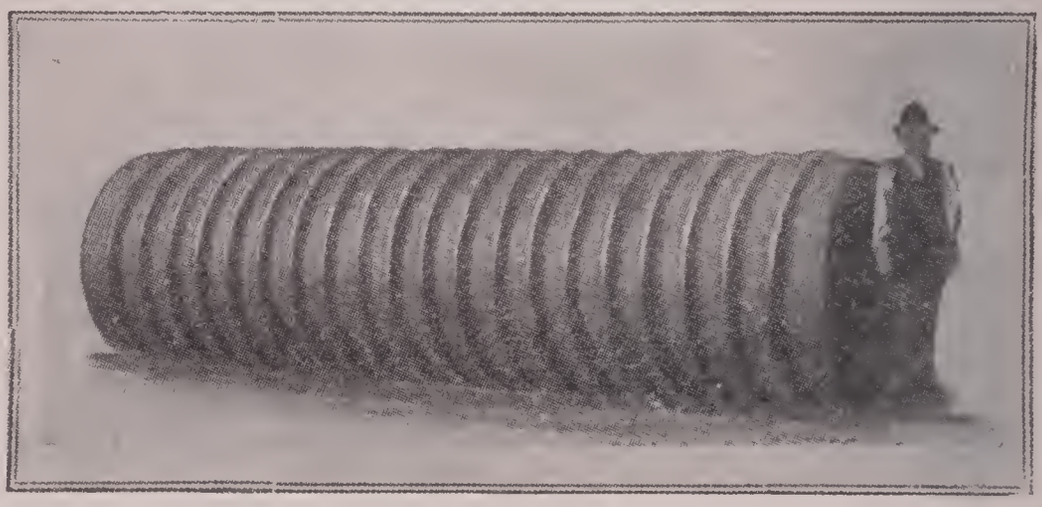


Fig. 10. The Morrison Furnace.

Adamson Furnace, Diameter, Thickness, Greatest Distance Between Rings?—The Adamson furnace tube consists of a series of rings welded at their longitudinal seam and having the ends of the rings flanged and riveted together, and so forming the furnace. In inspecting an Adamson furnace see that it is properly constructed, viz., length of rings between centers of flanges should be 120 times the thickness of the plate in inches minus 12. Radii of flanges on fire side 1½ inches. Depth of flanges from fire side should be three times the diameter of the rivet plus 1½ inches. The thickness of the flanges should be

as near the thickness of the plates as possible. The distance from edge of rivet holes to edge of flange should not be less than the diameter of the rivet, and the diameter of the rivet 3/8-inch greater than the thickness of the plate. The depth of the ring between the flanges should be no less than three times the diameter of the rivet. The following is the rule for determining the working pressure:

$$\frac{9900 \times T}{3 \times D}\left(5 - \frac{L+12}{60 \times T}\right) = \text{working pressure, where}$$

T=Thickness of plate in inches.
L=Length between centers of flanges in inches.
D=Outside diameter of furnace in inches.

When the longitudinal seams are riveted instead of welded, use 8800 for a constant instead of 9900. Fig. 11 shows a section of an Adamson furnace, and will give you an idea of its construction.

Is Heat Localized or Well Distributed?—This is one of the more important features, as with heat localized you not only can not obtain the maximum efficiency from either the boiler or the fuel, but you are liable to cause damage to the boiler owing to the concentration of heat on one part of the shell. The cause of improper distribution can usually be traced to defective or improperly located bridge walls.

Draught?—State whether natural or forced, also if possible give volume, which can be obtained by calculation, using the height and inside diameter of the stack as a basis.

Distance of Fire Grates from Crown or Tubes?—Obtain by ordinary measurement.

Area of Grates?—Length multiplied by width.

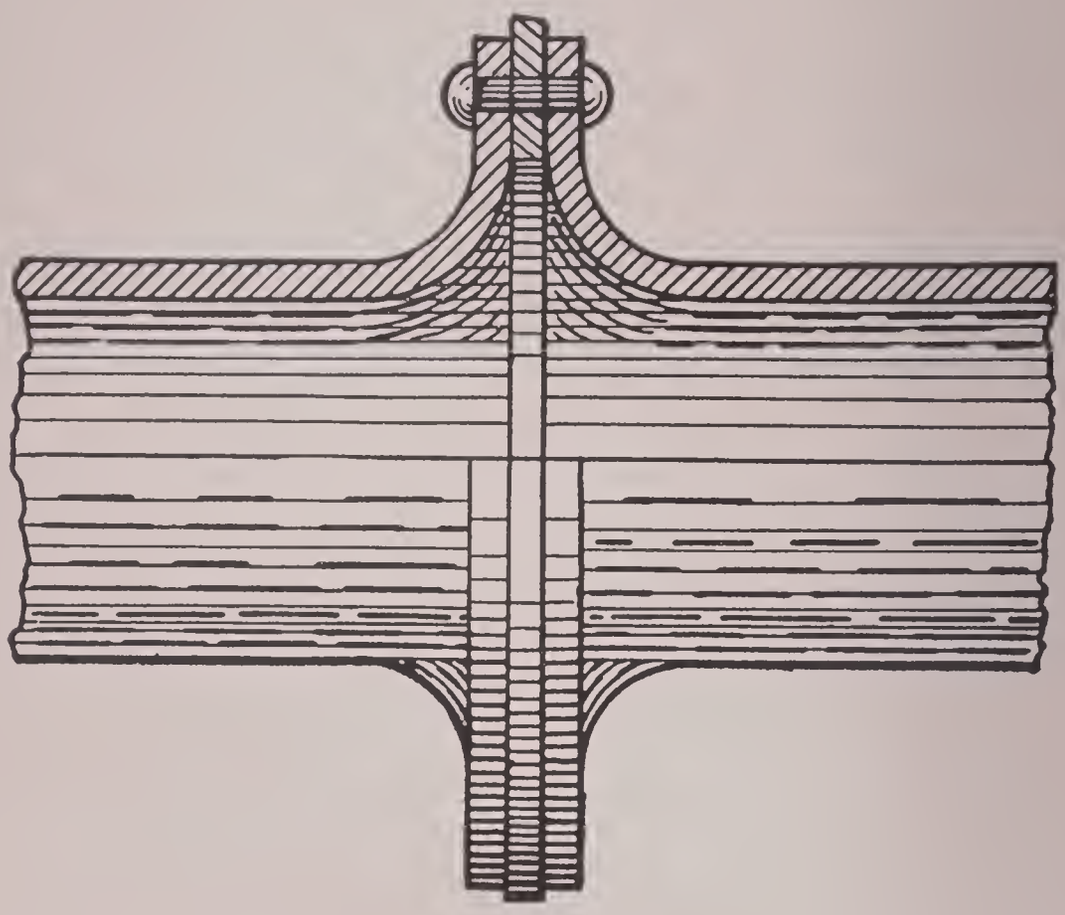


Fig. 11.

Diameter of Safety Valve?—This is important, as the safety valve must be of sufficient diameter to relieve the boiler promptly in case of pressure being excessive. The 1905 government rule is: The area of the safety valve must be equal to

$$2074 \times \frac{W}{P} = A, \text{ in which}$$

A=Area of safety valve in square inches per square foot of grate surface.

W=Pounds of water evaporated per square foot of grate surface per hour.

P=Absolute pressure per square inch, or working or gauge pressure plus 15 pounds.

If this gives an odd sized valve use the next larger standard size.

Pop or Lever?—Pop valve is one actuated with a spring. Lever valve, one actuated with a weighted lever.

Safety Valve: Stipulated Pressure? Weighted at What Pressure?—Some engineers through ignorance or recklessness will sometimes carry more pressure than the factor of safety permits. As a rule on all modern boilers the stipulated pressure is shown either on a brass plate fastened to the front or by being stamped into the plates. Where the stipulated pressure is not shown it should be calculated by the regular rule, and if it be found that the pressure carried exceeds the stipulated pressure attention should be directed to it.

Ordinary Working Pressure?—The working pressure is usually about five or ten pounds less than that at which the safety valve is weighted or set for.

Does Safety Valve Work Freely?—Have the pressure run up until the safety valve lifts, and notice if it lifts quickly and relieves the boiler promptly. Notice if the pressure continues to increase with the safety valve open. This is sometimes the case when the valve has insufficient lift or a restricted opening. The safety valve is what its name implies; see that it performs its functions.

Are There Stop Valves Between Boilers and Safety Valves?—The practice of putting stop valves between the boiler and safety valves should under no circumstances be permitted. The stop valve is a factor of danger, as it is likely to become closed, in which case the safety valve can not perform its functions, i. e., relieve the boiler of any excess pressure. Safety valves should be so arranged that under no circumstances can they become inoperative.

Relative Location of Check and Stop Valves?—This question is asked to make it imperative on the inspector to see exactly how the safety valves are located, as in some instances safety valves have been screwed into a section of pipe having a stop or check valve between the safety valve and boiler; in other cases safety valves have been put into the steam drum. Notice the location of the safety valve carefully, and also if any intervening valves between it and the boiler.

Can Water Collect in Steam Pipe with Stop Valves Closed?—The slope of all steam pipes should be toward the boiler, so that if stop valves are closed all condensation will run back into the boiler by gravity.

Is There Any Drip for Draining Off Condensed Water?—In cases where it is not possible to give all steam pipes the necessary fall to allow water to drain back, such pipes should be fitted with drip or drain pipes; these should always be tapped into the lowest part of the steam pipe. Therefore, look for pockets in this pipe where water is liable to collect.

Any Recommended?—Recommended as above.

Is an Engineer Constantly Employed?—This does not mean, are the engineers paid for being on duty continually, but are they really there, on the job. Cases have been known where the engineer turned over his plant (especially if a small one) to a small boy to watch while he went down town for something. Now the small boy is no engineer, and in case anything went wrong could do nothing. A man paid to take care of a boiler plant should do so, and not delegate the duty to some one else. There is too much at stake.

Has He Any Other Duties?—This refers to the engineer. Many owners, managers, shop foremen, etc.,

seeing the engineer walking about his engine or boiler room, form the opinion that he is idle, or, if not idle, that he has not enough work to keep him busy, and therefore add other duties to those he is expected to perform regularly. "Give him his tonnage," as the popular railroad expression has it. There is no harm in giving the engineer work enough to keep him busy, providing such additional duties do not take him out of his engine and boiler room, or so divert his attention as to prevent him from performing his regular duties. Nine-tenths of the boiler explosions, if traced down, will reveal the fact that the engineer, in addition to taking care of his plant, was supposed to look after several other duties. The engineer walking about his engine and boiler room, alert, watchful, is not idle, regardless of appearances. Give this question careful attention.

Give Horizontal and Vertical Center of Braces on Head?—These measurements can be obtained while inside inspecting the braces, and should be taken very carefully, as the braces are all that stay the flat surfaces.

Number and Size of Braces Used on Each Head?—This information of course can be obtained as above. Longitudinal braces extending from head to head will of course count as a brace in each head.

Diameter of Staybolts at Top of Thread?—Staybolts are the bolts used for staying flat surfaces, and differ from braces in that they are screwed through both sheets. They are commonly used in boilers having rectangular fireboxes, and when inspecting the boiler each staybolt should be tested by sounding with a light hammer, to see if broken, as on account of the vibrations and stress to which they are subjected they fre-

quently fail, and in this case naturally throw the load they were intended to support on the surrounding bolts.

Pitch, Horizontal and Vertical?—The pitch of the staybolts is the distance from center to center. The pitch of the staybolts is an important item and should be noted with care to see that the bolts are not carrying an excessive load. The United States inspection rules limit the strain on staybolts to 6,000 pounds per square inch of bolt area, this area to be calculated from the bottom of the thread. Another rule is to use 10 as a factor of safety, that is, the load or strain per bolt is to be but (1/10) one-tenth of the tensile strength.

Total Number and Size of Rivets in Braces on Head?—The object of this question is to see if the riveting conforms to the bracing, as sometimes the braces while of ample strength in themselves are riveted or fastened to the boiler with so few or such small rivets as to materially decrease the value of the brace as a support. A brace is like a chain, no stronger than its weakest part; therefore the foot of the brace should be of sufficient size to permit the use of sufficient rivets to make the fastening equal to the brace.

Is Manhole Opening in Shell Girthwise?—That is, is the shortest diameter of the manhole parallel with the boiler lengthways? The manhole should always be cut into the boiler (if cut into the cylindrical course) girthwise, as if cut lengthwise it not only weakens the boiler but is hard to keep tight. The better plan where possible is to put the manhole into the flat surface of the head.

Size of Opening?—Manholes are usually in the form of an ellipse; therefore give both diameters.

Wrought or Cast Reinforcement?—In all large manholes it is necessary to rivet a reinforcing ring around

the opening. This can be either wrought or cast. The best, however, is of the pressed steel shapes.

Number of Tubes?—If tubes are of different dimensions give number of each size.

Diameter?—Outside.

Length?—Over all.

Thickness?—Usually expressed in terms of Birmingham wire gauge (B. W. G.) or United States Standard (U. S.). Thus, No. 10 B. W. G.=.134 inch. U. S. 10 gauge=9/64-inch.

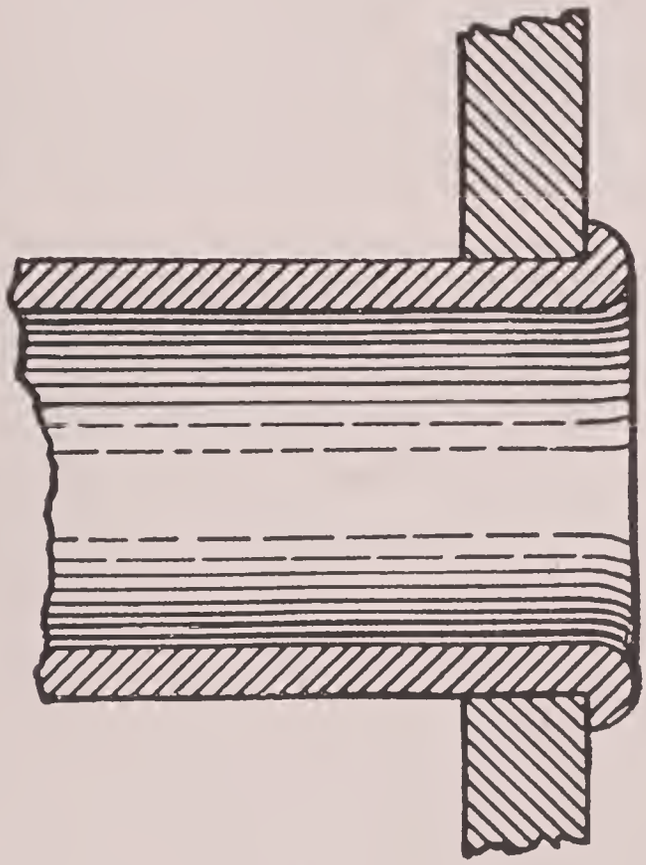


Fig. 12.

Are Tubes Beaded at Both Ends?—A beaded tube is one having the end turned over and hammered down (see Fig. 12). In a series of tests it was found that beading over the end of a tube increased its holding power fourfold over a plain tube simply rolled into a

sheet and not flared or beaded. In some boilers it is the practice to bead the tubes at both ends, in others to simply bead at the furnace end and flare at the other, while in others the tubes are simply rolled into the sheet without being either flared or beaded. This, however, on low-pressure boilers only, and then only on small tubes, two inches or less.

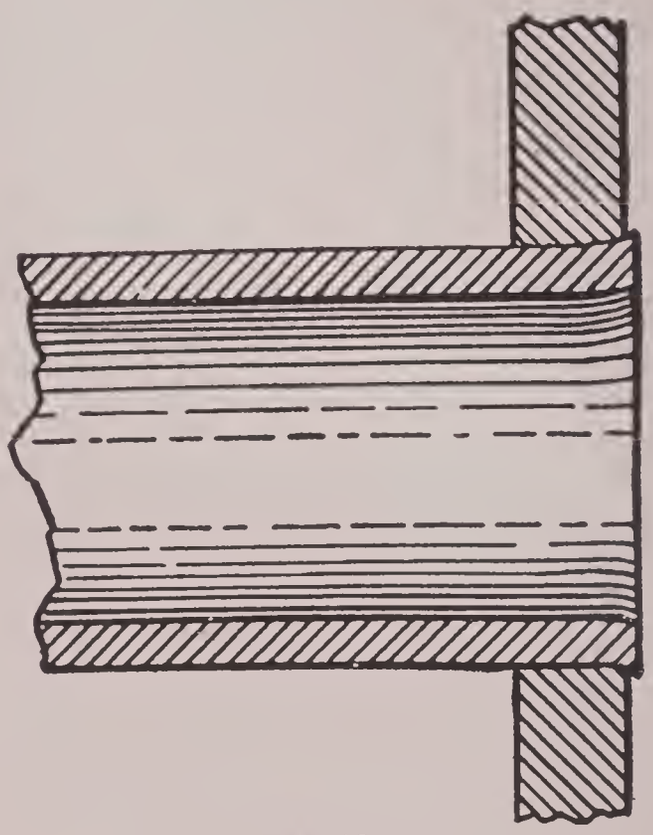


Fig. 13.

Which End Flared?—Flaring a tube consists of expanding it in a bell-mouth shape (see Fig. 13). The holding power of a flared tube is about equal to that of a beaded tube, the principal objection to its use in the furnace end being that there is little stock to work on in case the tube begins to leak.

If Tubes Enter Cylindrical Part of Drums, Give Distance Between Centers?—Refers generally to water tube boilers, and question is self-explanatory.

If Boiler is of Marine Type with Waterback, Give Bracing Over Crown Sheet?—The marine type of boiler is one of the most economical types of boilers used, in proportion to amount of space taken up. It consists of a large cylindrical shell whose diameter is about equal to its length, in the lower part of which are contained the furnaces, while the center is taken up with smaller tubes, the upper part being reserved for steam space. When this type of boiler is fitted with waterback the bracing over the crown sheet is of first importance, and therefore must have close inspection.

If Boiler is of Vertical Submerged Type, Give Bracing on Upper Cone and Head?—The usual and most satisfactory method of bracing the upper cone and head in a boiler of this type is by means of staybolts (see Fig. 14), as there is a large flat surface (the top head) which can not be well stayed otherwise to resist the upward and outward pressure.

Are Boilers Properly Braced and Stayed?—This means internal bracing and staying. Be sure to see that all flat surfaces especially are well braced to resist internal pressure, seeing that the area of the section covered by each brace or stay when multiplied by the pressure will not throw a strain to exceed 6,000 pounds per square inch of brace or stay area on any one brace or stay.

Distance from Upper Row of Tubes to Shell?—This should be sufficient to submerge the tubes at least four inches and then leave sufficient space for dry steam.

Is There Any Surface Blow on Boiler?—This is necessary where water contains such chemicals or solids as have a tendency to induce excessive foaming, salt water for instance. The foam can readily be blown off through

the surface cock. If this foam is not kept blown off, it may mislead in testing water level with gauge cocks.

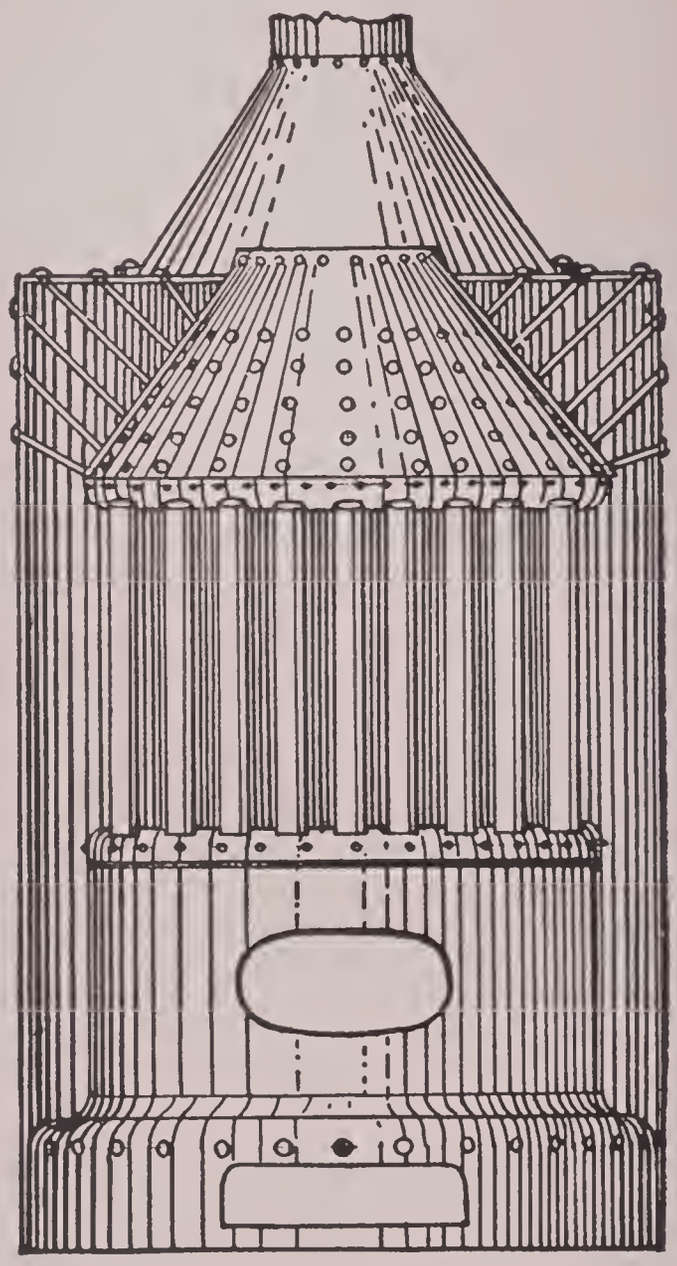


Fig. 14.

Fuel Used?—Where oil fuel is used, see that the burner does not allow the jet of flame to strike directly against a small area of the furnace, but that the flame is spread to produce a uniform effect.

Thickness of Flues Over Six Inches in Diameter?—As the strength of flues, tubes and other cylindrical bodies decreases in the same ratio as the increase in diameter, it is essential that proper proportions be maintained to withstand the pressure carried.

Lap Riveted or Welded?—Be sure to specify, also state if single or double riveted, as a riveted flue is about 20 per cent weaker than a welded one.

Length of Sections?—Usually of a type similar to the Adamson furnace (see Fig. 11).

Where is Blow-Off Connected to Boiler?—In locating the blow-off cock the lowest part of the boiler should be chosen, and preferably the end opposite the furnace end. The object of the blow-off cock is to blow out the sediment which naturally settles in the boiler, and as this sediment will gravitate toward the lowest part the blow-off cock should be located at that point. This in boilers of the locomotive type will place the cock in the leg, and of course at the furnace end, but as the water is introduced at the front end and carried back by the circulation almost immediately, the greatest quantity of mud would be collected in the leg. In boilers that are bricked up an opening should be left in the brickwork large enough to clear the blow-off pipe, as if bricked up tight the condition of neither the joint nor the plate can be seen, and, owing to the expansion and contraction of the boiler, the cock is liable to become loosened and may blow out without warning.

Size of Blow-Off Cock?—Should be large enough to avoid possibility of becoming clogged.

Reduced in Size?—The orifice should be as large as the inlet.

Is Blow-Off Cock Properly Protected?—Should be so

protected as to avoid the possibility of becoming accidentally opened, or of being broken off.

Valve or Cock?—Blow-off cock may be either plug cock type or gate or globe valve. Of the three, the gate valve is preferable.

Position of Feed?—The feed water inlet should be as near the top of the water level as possible, and always as far removed from the furnace as the construction of the boiler will permit. The water fed into the boiler, being colder than the water contained in the boiler, will naturally go to the bottom, then flow back to the furnace end to take the place of the water being evaporated or converted into steam. This is called circulation, and upon a good circulation depends the efficiency and steam making qualities of the boiler.

Size?—Should be of sufficient size to permit water to be fed to the boiler more rapidly than it can be converted into steam.

Are Feed Valves in Good Condition?—The check valves or feed valves must be kept in good order and tight, as in case the boiler is fed by means of an injector, a leaky check valve may prevent the injector from working at a time when it is most needed.

Pump or Injector?—If pump, it should be of a type that throws a continuous stream, to prevent hammering.

Can Feed Pump and Injector be Operated When Main Stop Valve is Closed?—The pump and injector should be so connected as to be operative at all times regardless of main stop valve, and for this reason should take steam direct from the boiler or steam drum.

Feed Water Heater?—This utilizes the heat of the exhaust steam to heat the feed water before it is fed into the boiler, and is quite a factor in fuel economy. Where

water can be heated above 150 degrees it is necessary to use a feed pump instead of an injector, as the injector will not handle water above that temperature.

Does Cold Water Enter Boiler Near Hot Plates?—This should not be permitted under any circumstances, as it is not only very uneconomical, but is liable to cause serious damage to the boiler through cracked plates, etc.

If H. T., Do Gases Return Over Shell?—In some forms of externally fired horizontal type of boilers the gases first pass under the boiler, then back through the tubes, then forward again over the top of the boiler. In inspecting a boiler of this type, examine it carefully where the bridge walls come in contact with it.

Water Source?—Knowing the quality of the water will often give one an idea of the condition of boiler. As for instance, if pond water is used that is highly impregnated with acids or chemicals from neighboring mills or factories, the probabilities are that the boiler will be pitted.

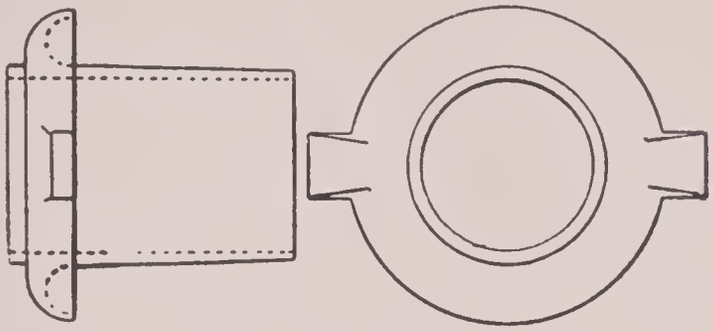
Quality?—All up-to-date steam plants should have an analysis of their feed water. If not it is advisable to get it. However, an approximation of the quality of the water can be arrived at from the appearance, taste, smell, or nature of the scale or sediment deposited.

"In conclusion, we wish to emphasize the fact that the inspection of a boiler should never be carried out in a careless or perfunctory manner, but should be slow, careful and deliberate, going carefully over every item. The shell should be sounded from the inside with sharp hammer blows for evidences of lamination, and each seam should be carefully inspected, especially just at the end of the lap, for evidence of grooving, and—last, but not least—don't take the other fellow's word for it, but see for yourself."

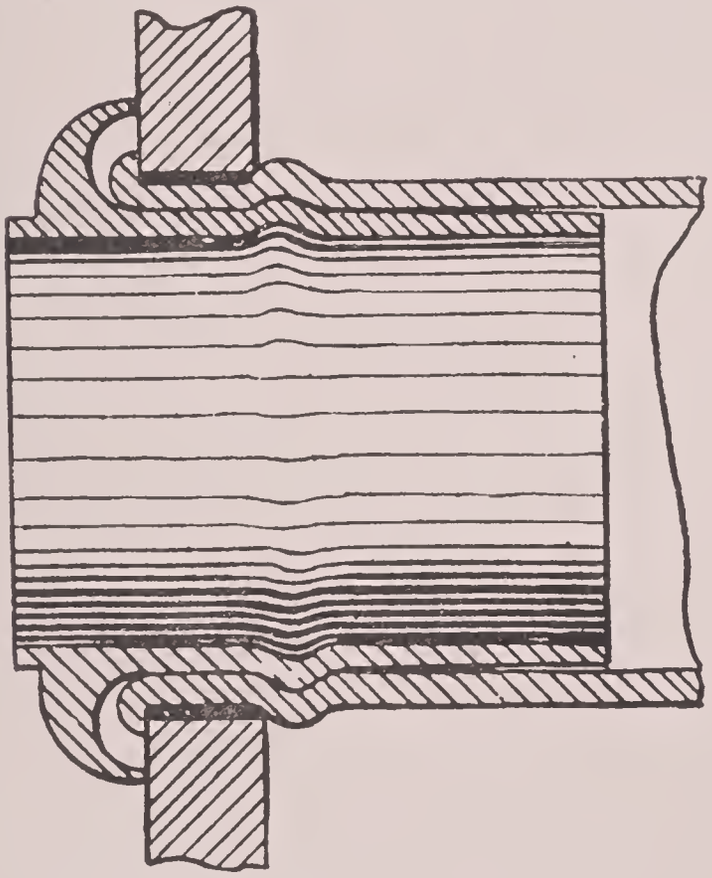
FLUE TROUBLES.

Flue troubles are principally due to expansion and contraction, vibration and the effect of heat and cinders at the firebox end. Where good water was used in the old type of deep firebox boiler equipped with a good brick arch, flues frequently lasted eight to ten years. On the same lines, on modern engines with shallow fireboxes and long flues, the average life of a set of flues is not much over one year. The decreased life is so great as to warrant careful investigation and every effort towards a remedy. A firebox designed deep enough for a good brick arch will reduce the bad effect at that end. It will also aid combustion. It is difficult to determine the effect of vibration in long flues. In many cases an attempt to overcome it is made by using flues of larger diameter. An objection to this is that smaller flues give better steaming qualities. It would seem possible that still another flue sheet could be placed midway the length of flues to remedy the vibration. The effect on the water circulation could possibly be obviated by supporting the top half of the flues with one plate and the bottom half with another placed adjacent to the other and separated sufficiently to allow circulation. A device known as an Emergency Thimble has been invented and patented by Mr. Max Toltz, by means of which emergency repairs may be quickly and temporarily made. This device can be readily inserted into, or withdrawn from, the end of a flue, when leakage is caused or threatened by reason of the burning away of the exposed parts. The thimble covers the exposed end of a flue and so seals the joint on the inside of the flue sheet.

The illustration represents the flue sheet of a tubular boiler, with a flue secured in place in the usual way. In ordinary practice the projecting end of the flue which is



EMERGENCY THIMBLE FOR FLUES.



EMERGENCY THIMBLE IN PLACE.

rolled over on the outside of the flue-sheet forms a head, while just inside the flue-sheet, the flue when expanded, forms an annular depression which seals the joint between the flue and flue-sheet on the inside.

The "emergency" consists of a short piece of tube made to fit snugly into the flue and externally tapered towards its inner end, to facilitate insertion into the flue and for removal therefrom. Near to, but not quite at, its outer end, it is formed with a rearwardly cupped circular flange large enough to extend beyond the bead and touch the outside of the flue-sheet, thereby covering the exposed end of the flue and protecting it and the adjacent portion of the flue-sheet. To enable the thimble to be driven into the flue without injury to the bead, the tubular portion of the thimble is extended beyond the flange so as to form a projection in line with the tube and upon this projection the hammer blows are received.

The thimble is preferably a drop forging of steel or malleable iron so that when driven into the flue, it may be rolled or expanded just inside the flue-sheet. By rolling it into the flue, and thereby expanding the flue as well, the joint between the flue and flue-sheet on the inside is sealed.

To facilitate the withdrawal of the thimble from the flue, the thimble is made with laterally projecting lugs, one at each side. By driving a wedgeshaped tool between the flue and the lugs, the thimble can be forced out of the flue. By the use of an emergency thimble, when injury takes place, or leakage is threatened at the joint between the flue and flue-sheet, it may be stopped or patched up as it were, without removing or replacing the flue, until such time as regular repairs can be made. The idea in the emergency thimble is to stop a leak and yet keep the boiler-tube in service for the time being. It is, of course, not designed to be a permanent fixture, but is useful for what it is intended, an emergency.

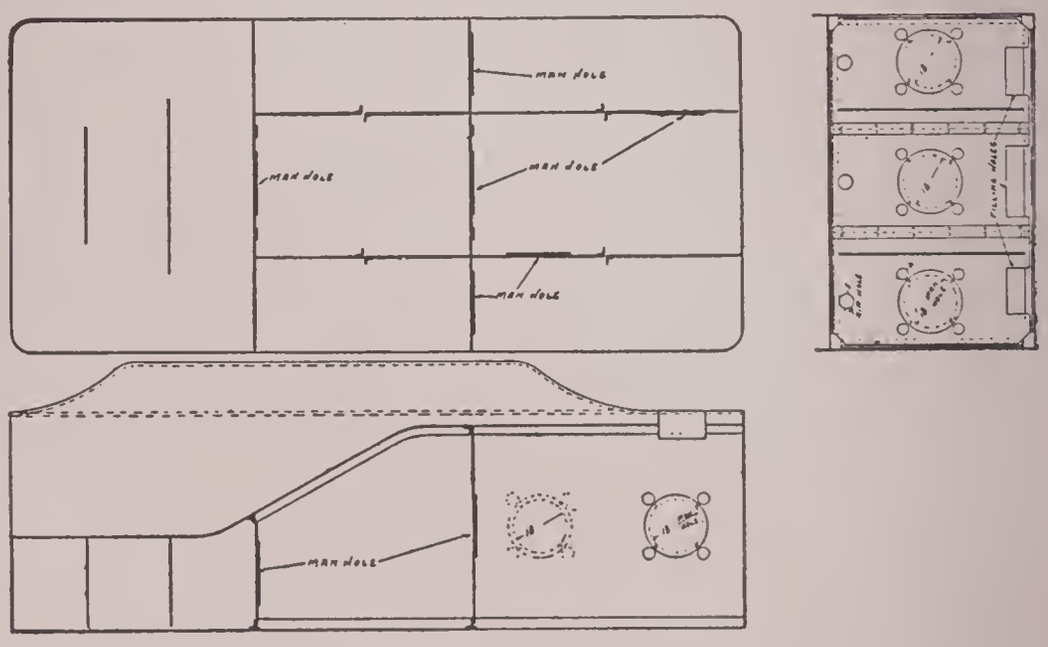
DERAILMENT OF TENDERS.

The causes generally given for derailment are, in part, as follows, according to an authority, (T. A. Lawes, M. E.) writing in "Railway and Locomotive Engineering," who states that "Bad track, the use of side bearings on front trucks, the omission of side bearings on front trucks, truck bolsters not clearing arch bars, wheel base too short, center of gravity too high, rigid coupler at rear of tender, the side bearings wider than rails," are largely responsible for tender derailments.

In the spring the action of frost is bound to make track bad, and that bad condition will continue until the track is lined up. This authority believes that it is a poor excuse to lay derailments to bad track, which, while it allows the engine to pass over safely, derails the tender, and he says he has never been able to find a convincing reason for the use of side bearings on front trucks. On a four-wheel engine truck carrying a heavy load, he thinks side bearings are not necessary. On an uneven floor, a three-legged stool is stable while a four-legged stool is unstable. The two side bearings on the rear truck with the center bearing on the front truck make a stable condition. With side bearings on the front truck, however, we have an unstable condition. On bad track, side bearings on the front trucks cause strains which would not be there if the side bearings were omitted.

On account of large and heavy capacity tanks requiring large spring space, designers of locomotives sometimes do not make bolsters to clear the bottom arch bar sufficiently. In the rolling of the tank, if the bolsters do not clear the arch bar, the tendency is to lift the

wheels off the track. It would be well if engine tanks had longer wheel bases. However, as so many round-houses were built when engines were shorter than they are now, it is impossible to increase the length of the wheel base without increasing the length of the round-house. The value of a longer wheel base cannot therefore be questioned. Radial couplers, with which modern tenders, as a rule, are equipped, are of great advantage in passing curves.



Arrangement of Swash Plates in Tender.

Derailments take place most often he has found, at high speed with the tank about two-thirds full of water. As a rule, examination revealed the tank to be in good condition and low places on the track. Generally it is the rear truck that derails. A tank (capacity of 6,500 gallons) containing 5,000 gallons of water, weighing about twenty tons, which is on a track having a succession of low places, oscillates and throws the water from one side to the other,—twenty tons of water allowed to go where it will. In the stowing of cargo on ocean

vessels great care is taken to place each article so it cannot shift when the vessel rolls, thus endangering its stability. The shifting of water in an engine tank can largely be prevented by the use of longitudinal baffle plates. Baffle plates arranged at right angles with the track are in general use but longitudinal plates are limited in use.

The accompanying drawing shows a tank with two cross baffle plates, and two longitudinal baffle plates, dividing the tank into seven compartments. Access is had from one compartment to another through an eighteen-inch manhole, closed with a plate held by four bolts. Access to the bolts is had through the small holes which are open. The plates have openings at the bottom to admit the passage of water from one compartment to another. In a test, a float placed in a tank, without longitudinal plates, and running at the rate of forty miles an hour, had a maximum movement up and down of ten inches. In a tank equipped with the plates, the float had two inches maximum movement.

A passenger engine tank of large capacity should, he thinks, have longitudinal baffle plates, side bearings omitted on front truck, truck bolsters with proper clearances on arch bars, radial couplers, distance between side bearings less than the distance between rails.

Tenders of modern high capacity, of the steel bolster, inside hung brake beam type, are liable to derailment, according to another authority (F. P. Roesch), writing in the same periodical from the causes set forth, viz.:

"Fig. 1 is a rear view of a tender showing the section through the rear truck just ahead of the back pair of wheels, so as to show the bolsters, springs, side bearings, etc.

"The view shows the tender on an even keel with cistern half full of water. The side bearings are shown in full lines and placed inside the arch bars. The point where outside side bearings would be located in case applied is shown at the extreme ends of the bolsters and in dotted lines.

"Were the track perfectly straight and smooth the entire load could be carried on the center casting and the side bearings dispensed with in perfect safety. As this is a condition that does not obtain, however, the side bearings are added to catch a part of the weight, as the tender strikes a curve or the truck drops into a low place in the track, and so prevents the body of the tender from being rolled clear of the trucks.

"We know that as a tender enters a curve, and especially if at a high speed, that the action of the centrifugal force has a tendency to impel it at a tangent, or, in other words, to the outside of the curve; this causes a change in the distribution of the weight on the truck, due partly to the shifting of the fluid load (water) and partly to the impulse imparted to the body of the tender by the centrifugal action referred to.

"The weight which on level track was carried entirely by the center casting is now distributed between the center bearing and the outer side bearing. This side bearing, therefore, in conjunction with the bolster, the spring-seat, the arch bar and the axle journal, all form a series of levers and fulcrums, all having a definite action on the stability of the truck, and which action must be traced in order to determine wherein the design is defective.

"Assuming that the tender is entering a curve of a stated radius at a certain speed. The centrifugal force has a tendency to impel the tender forward in a straight

line instead of following the curve; this tendency, however, is overcome so far as the truck is concerned by the wheel flanges acting against the outer rail, thus keeping the truck in bounds. The body of the tender, however, being but loosely supported on the center bearings is free to move to the extent of the side bearing clearance and the compressiveness of the springs; the centrifugal force therefore produces the effect of a heavy blow delivered to the bottom side bearing by the kinetic energy of the tender body. The striking force of the blow so delivered is hard to calculate to a nicety, but is above the weight originally carried by the center bearing, and can be expressed as follows:

$$F=\frac{W V^2}{2 g R}$$ where

W=Weight of striking body in pounds.
V=Velocity of striking body in feet per second.
g=The constant 32.2 = acceleration due to attraction of gravitation.
R=Amount spring is compressed in feet.
F=Force of blow in pounds.

"Hence it will be seen that the force of the blow is in ratio to the side bearing clearance, every increase in clearance increasing the blow proportionately.

"Let us now trace the effects of the blow as delivered. It is first received by the truck side bearing, and thence conveyed to the truck bolster; from there it passes to the spring where the violence of the shock is converted from a direct blow to a push, the moment remaining the same; It now passes to the spring plank, thence to the arch bars, to the journal boxes, to the journal and then back through the wheel to the rail. It will thus be seen that

we simply convert the axle into a lever, the force being applied to one end, or journal, the wheel at the same end acting as a fulcrum, while the other end of the axle, together with the wheel and truck side, represent the weight to be raised.

"With the exception of the centrifugal action on the truck, the moment of all the other movements is governed by the kinetic energy of the body of the tender, and this energy is combined with the centrifugal action on the truck in such a manner as to raise the wheels bodily off the rail on the inner side of the curve, and hold them suspended while this force has been dissipated or until normal conditions have been restored by the tender coming out of the curve. It is at this point that trouble generally begins. In case the kinetic energy of the tender was sufficient to raise the wheels enough to clear the flanges, or if the build or condition of the truck is such as to produce a like effect, the wheel in resuming its natural position, may fall with the flange on top of, instead of inside of, the rail, and the spring action on the loose body of the tender, giving the entire load an impulse in the direction opposite to that imparted by the centrifugal action, will cause the wheel which now has the flange riding on top of the rail, to take an outward course and consequently result in derailment.

"This is borne out by a careful study of tender derailments. In nearly all cases of curve derailments it will be found that the truck left the rail on the inside of the curve, or the tangent immediately following the curve, while on straight track derailments where kinetic energy alone obtains, the wheel will drop off outside of the rail opposite the low spot which first caused the rocking.

"In order to trace the effects of the rolling or tilting

of the tender and its effect on the truck more readily, we call attention to Fig. 2, which illustrates this without the intervention of springs, arch bars, etc.

"When the tender enters a curve at speed or strikes a low place in one side of the track on straight line, so as to cause a rocking of the tender, the major portion of the weight is momentarily transferred from the center to the side bearing. In Fig. 2 we assume that the pitch of the tender was toward the right. We therefore have a redistribution of the weight originally all carried by the center bearing (a) so that side bearing (b) will now take a part of it. To that part of the weight transferred to the side bearing, however, we must add the speed or force at which it was transferred, and would therefore be equal at the journal (c), if delivered direct, to, $\frac{WV^2}{2gR}$, but as the other end of the lever rests on the journal (d) a part of this force is necessarily transmitted to that point, the amount being governed by the location of the side bearing in relation to the spring saddles E and K. It is a downward push called C, and exerted at the end of the axle at the point marked C and it would be expressed thus,

$$C=\frac{\frac{WV^2}{2gR}\times(H\text{-}y)}{H}$$

The downward push at point D at the end of the axle, and called D, would be,

$$D=\frac{\frac{WV^2}{2gR}\times(H\text{-}x)}{H}$$

and the force, C, resolved into lifting force, L, would equal at the end of the axle, at the point, D,

$$L = \frac{C \times S}{I}$$

and with the side bearings placed as in Fig. 2 would give 60 per cent. of D a change in the position of the side bearing b, to a point nearer the arch bar, however,

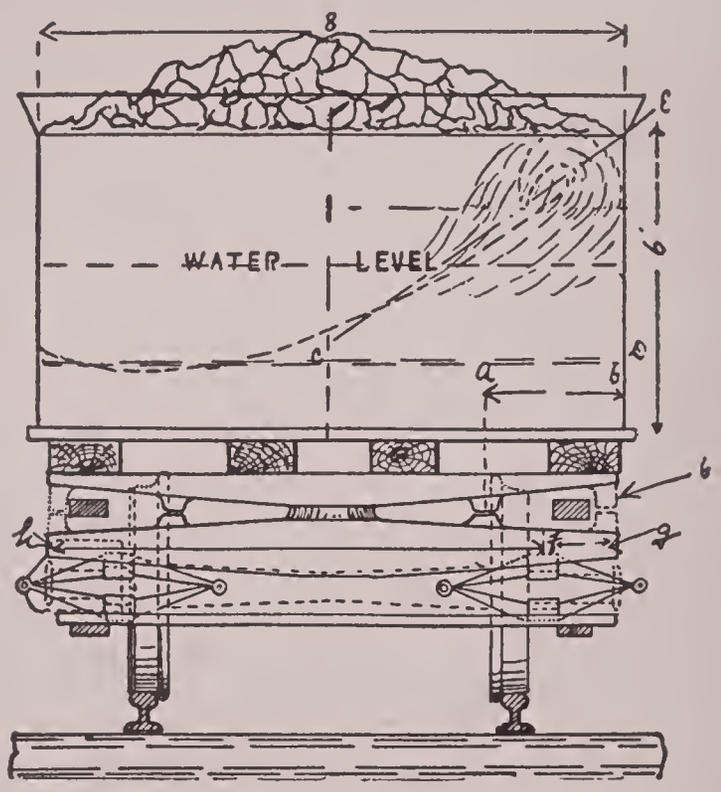


FIG. I. REAR VIEW OF TENDER.

would produce a balance between the downward force at D and the lifting force, L, at D—as moving the side bearing toward the arch bar decreases the downward force at D and at the same time increases the lifting force, L—so that the two forces would become equal, and therefore leave nothing but its own weight to hold the truck to the rail on that side.

"From a casual glance it would appear that the best way to reduce the lifting force, L, at D would be to move the side bearing (b) inward toward the center, thus decreasing the distance, b-d, and increasing the distance, b-g. A glance at Fig. 1, however, will show that this would increase the force, F, by the additional overhang of the tender body, which now enters into the calculation. With the tender on an even keel, the weight as said before is carried on the center bearing (a), Fig. 2.

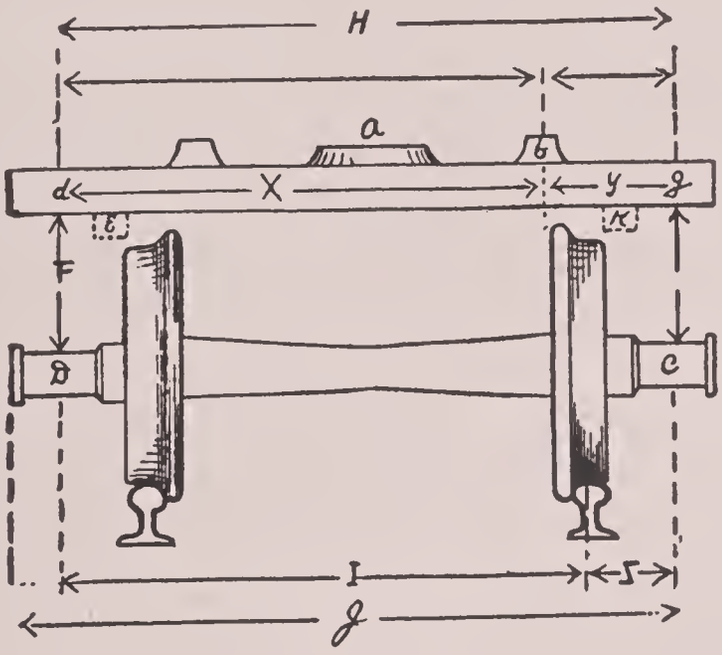


FIG. 2. SKELETON DIAGRAM OF TRUCK.

With the shifting of the body as in curving, a tilting action is produced in direct ratio to the distance, a-b (Fig. 2), and were this distance decreased to any extent by moving the side bearing (b) inward, the overload due to the shifting of the water in the cistern, together with the kinetic energy of the tender body, would be sufficient to completely overturn it. The difference in the weight carried on either side of the center bearing when the load (water) shifts is shown by the angle, C, D,

E, (Fig. 1), the greater portion of which is shown as beyond the point, a, (Fig. 1) and thereby increasing the force of the blow, F.

"It is plain that any reduction of the force, F, would likewise reduce the lifting action, L, and consequently any decrease in the distance, a-b (Fig. 1) would be desirable. This might naturally lead to the conclusion that it would be well to eliminate the distance, a-b, entirely by moving the side bearing (a) to coincide with the point, b, that is, outward, to the extreme end of the bolster, as shown by dotted lines. With the spring seat in its present location, however, we here come in contact with another factor, which, unconsidered, will only lead to disappointment and further derailments. By this proposed change in location of side bearings it will be seen that the side bearing is thrown outside the arch bar and also beyond the spring seat, the spring seat therefore would simply act as the fulcrum of a lever having one arm equal to f-g and the other equal to f-h (Fig. 1), this in case of insufficient bolster clearance (between top of bolster and bottom of arch bar), or in case the bolster clearance were less than the side bearing clearance, would therefore tend to produce a lifting action on the end of the bolster at h equal to F multiplied by distance f g, and divided by the distance h f, calling these distances x and y respectively, we have the equation, lifting force at

$$h = F \times \frac{x}{y}$$

this added to the power, L, would easily raise the wheels clear of the rail.

"We see that we must therefore effect a compromise between the different forces, and this is no doubt exactly

what had been done in the seeming anomalous instances before noted. The logical compromise, as can be seen, is to move the side bearing to a point nearly over the spring saddle center, keeping between the spring saddle center and the truck center, however, and this is why in some instances freedom from derailment was obtained by moving the side bearings in, while in others equally good results were obtained by moving the side bearings out. In both cases the proper relationship between spring and side bearing was established, the springs not occupying the same position relative to arch bars in the different instances noted.

"The principles as stated are well illustrated in the latest type of Pullman sleeper trucks and accounts for their very easy riding qualities and comparative freedom from derailment."

STEEL TIRES—CAUSES OF DEFECTS AND FAILURES.*

With few exceptions the tires used in the United States are all made from (acid) Open Hearth Steel, its uniformity in quality and cheapness, as compared to crucible steel, having practically driven the latter out of the market. In Europe, whilst most tires are made by the Open Hearth process, and some by the crucible process, tires of (basic) Bessemer steel are also used. The conditions of service, especially as to wheel loads, are not, however, as severe as in America.

The grade of steel used for tires in Europe is much softer than that used in America, as shown by some of the typical analyses in the following table:

	American.	French.
Carbon	.55 to .75	.40
Silicon	.25	.10
Phosphorous	.05	.05
Manganese	.65	.66
Sulphur	.05	.065
Ultimate Tensile Strength	100,000 to 135,000	95,000
Elongation	2″, 20 to 10 per ct.	8″, 12 per ct.
Reduction	30 to 12 per ct.	

	English.	English Export.
Carbon	.36	.52 to .61
Silicon	.08	.19
Phosphorous	.055	.03
Manganese	1.25	.75
Sulphur	.05	.03
Ultimate Tensile Strength	85,000	107,000 to 123,200
Elongation	2″, 26 per ct.	2″ 17 to 14 per ct.
Reduction	39 per ct.	23 to 18 per ct.

*George L. Norris, M. E.

	German.	Krupp Export.
Carbon	.35	.55 to .85
Silicon	.15	.30
Phosphorous	.095	.06
Manganese	.38	.60
Sulphur	.04	.045
Ultimate Tensile Strength	90,000	105,000 to 135,000
Elongation	2″, 28 per ct.	2″, 17 to 8 per ct.
Reduction	38 per ct.	25 to 9 per ct.

Up to 1890 it was the general practice to make tires from short ingots, each ingot being sufficient to make only one tire. As it is practically impossible to cast an ingot of steel, no matter how small, without pipe and segregation in the upper end, tires made from short or single tire ingots are liable to contain defects from this cause. In manufacturing from a short ingot no cropping is discarded from the top of the ingot, the only discard being the small disc of metal punched from the center of the bloom.

About the year 1890 The Standard Steel Works conducted a series of tests comparing the tires manufactured from short or single tire ingots, and long ingots from which several tires could be cut, and the top portion of the ingot containing the piping and segregation discarded. A paper on the results of these tests was contributed to the American Institute of Mining Engineers, by Mr. A. A. Stevenson, M. E. As a result of these investigations The Standard Steel Works adopted the practice of making all their tires from bottom-poured long ingots, as the only way to reduce to a minimum the number of tires failing in service on account of casting defects in the ingot.

Both the long and short ingots are usually bottom cast in groups, fed from a central runner. The long ingots

are octagonal in section, about seventy-two inches long, and vary from thirteen to twenty inches across. The short ingots are usually cylindrical, though conical ingots

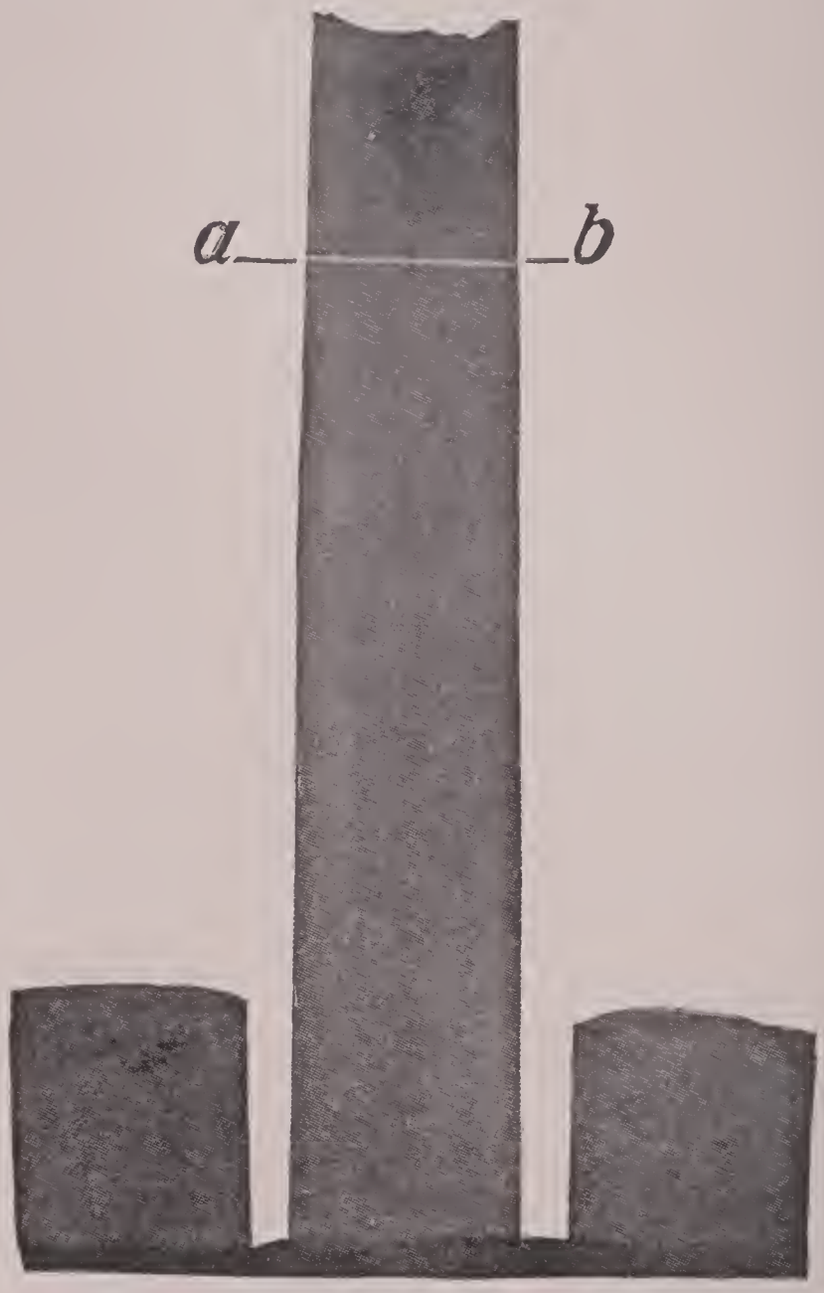


Fig. 2. Fig. 1. Fig. 3.

are common abroad, and have generally a dome shape top. They vary in diameter and height according to the size of tire to be made. Unlike the long ingot

Discarded Ends of Tire Ingots.

which remains fluid for some time and gives an opportunity for the steel to teem, and the gases and impurities to rise to the top, the short ingot sets quickly and the piping, gas cavities and other defects as compared with the long ingot, occupy relatively a larger portion.

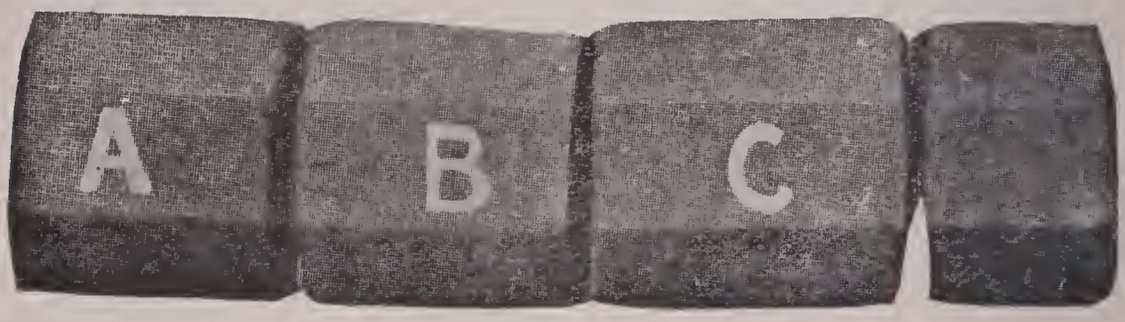


Fig. 4.

Even with the minimum amount of piping possible, the punching does not always entirely remove the defects

Fig. 5.

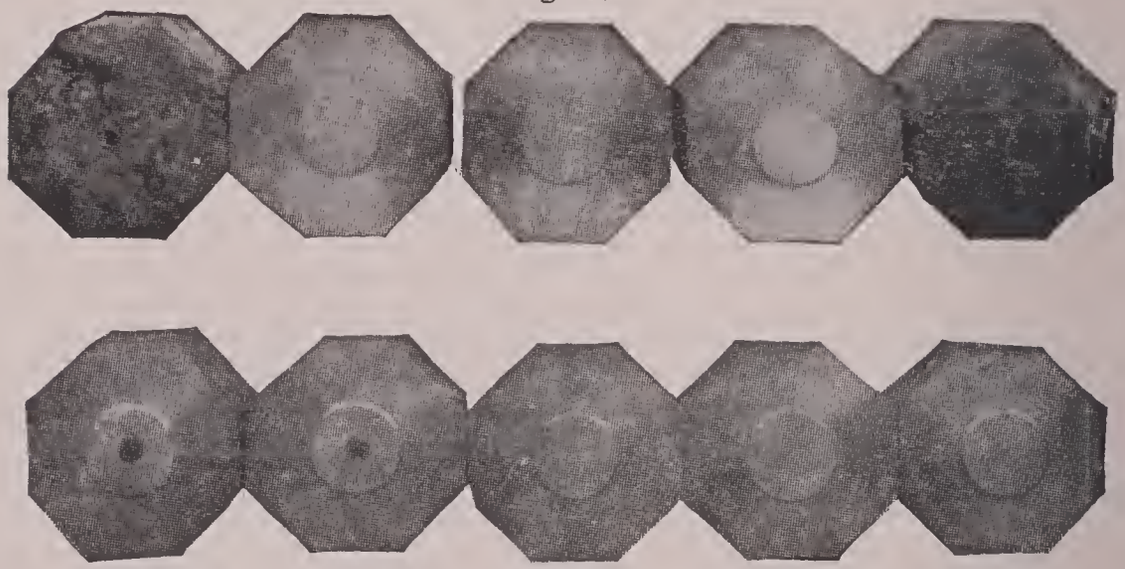


Fig. 6.

and consequently the tires made from short ingots more frequently contain these defects. The illustrations Figures 1 to 12 plainly show the superiority of the long

ingot over the short for manufacturing tires of homogeneous structure. Figure 1 is a full length section of a long ingot from which the piped portion above the line *a-b* is discarded, while Figure 2 is a section of the ordinary short or single tire ingot from which nothing

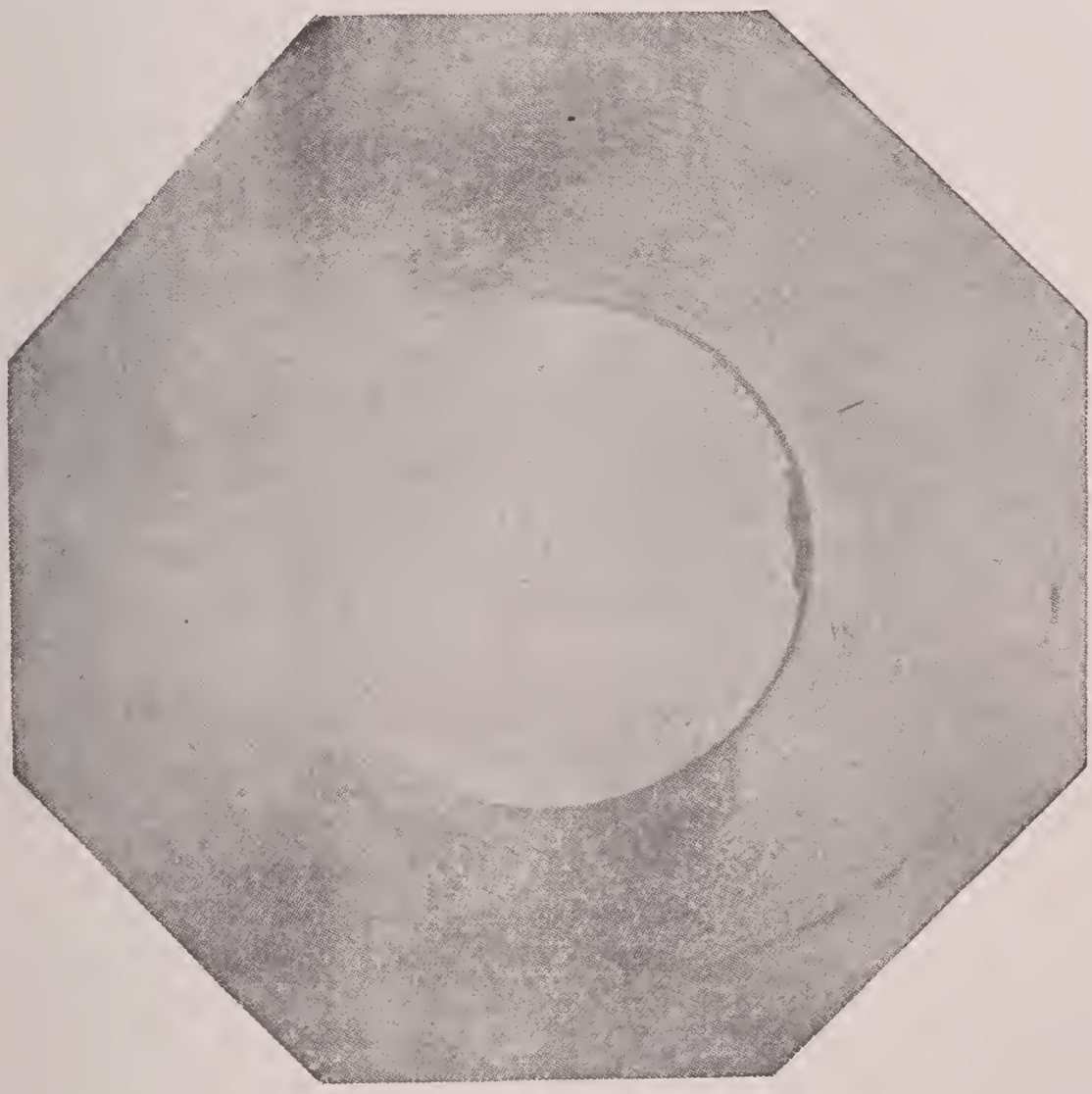


Fig. 7.

is discarded but a small thin disc in punching the bloom. Figure 3 is a section of a tire bloom from a long ingot. The contrast between it and the short ingot is very marked. Figure 4 shows the manner of cutting an ingot into tire blooms. Figures 5 and 6 show the fractures of a

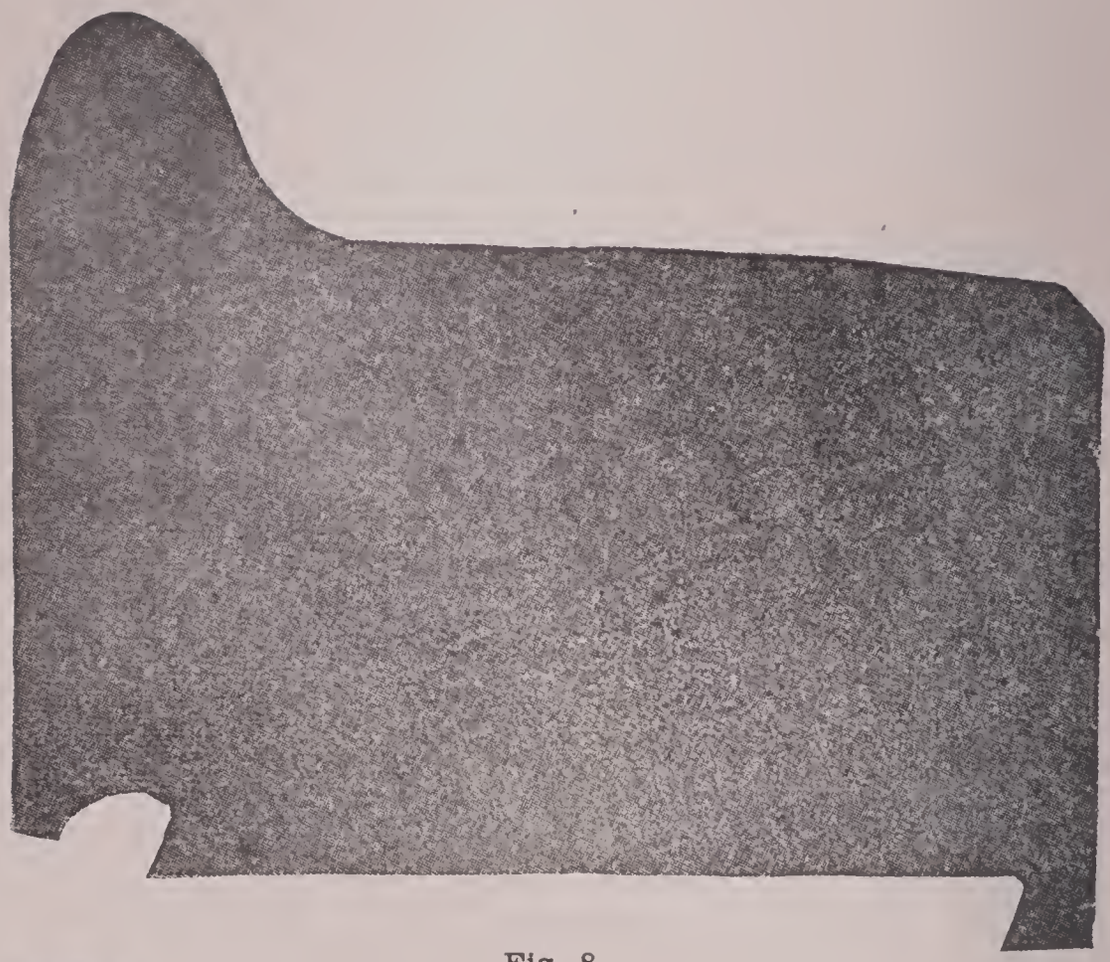


Fig. 8.

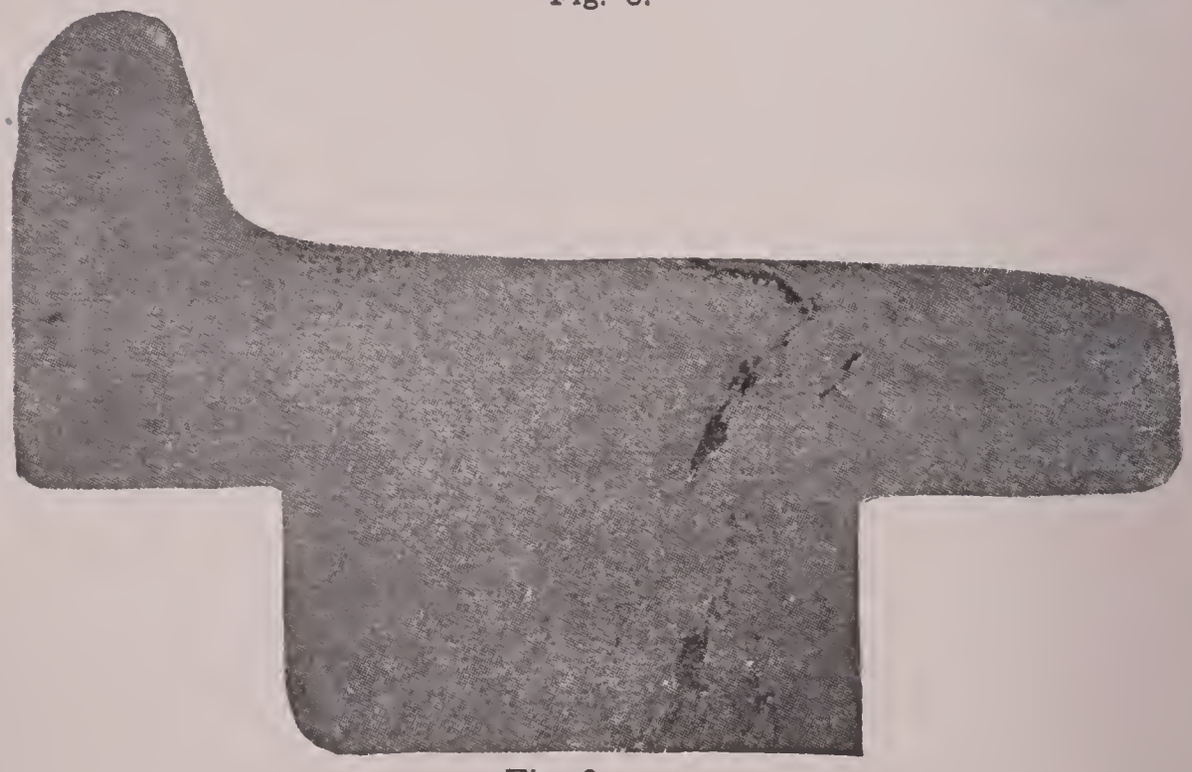


Fig. 9.

long ingot cut up into blooms, and Fig. 7 is an enlarged view of a typical fracture. The central pipe shown in the left hand blooms of Fig. 6 is punched out in forming the tire. Fig. 8 is an etched section of a tire made from a long ingot bloom, and shows the homo-

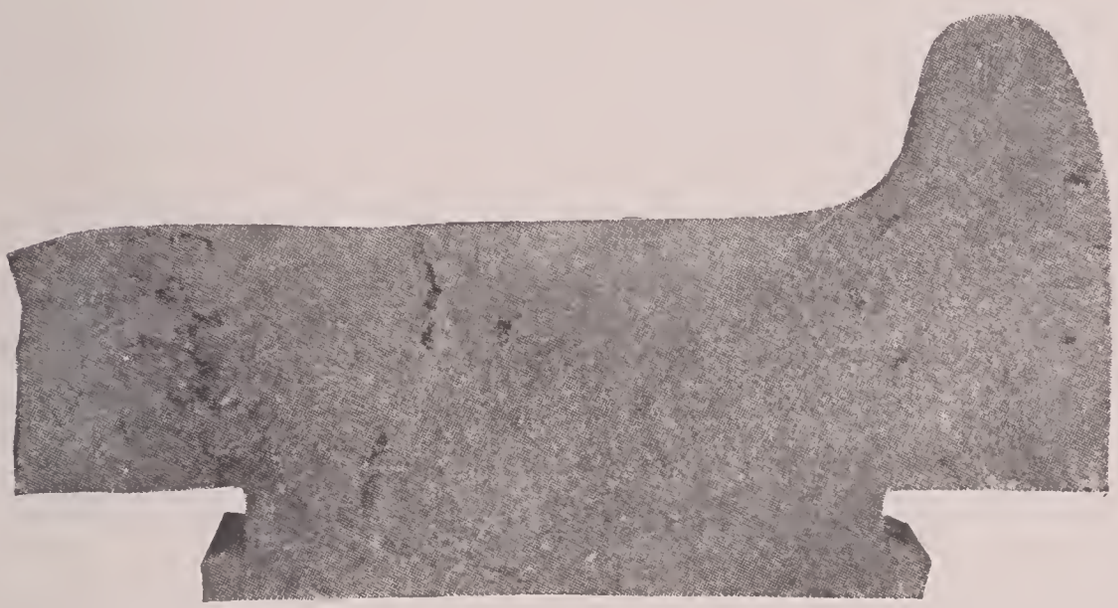


Fig. 10.

geneity of structure obtained by this method of manufacture. Figures 9, 10, and 11 show etched sections of tires made from short ingots, illustrating the presence of the original casting defects. Figure 12 is a section through a conical ingot such as is used to some extent in Europe. For soundness this possesses no advantage over the ordinary cylindrical, short ingot.

SHELLY TIRES

During the past few years owing to increased speeds, wheel loads and severity of service, steel tires have more frequently developed that condition on the tread commonly termed shelly or flaky spots. This condition is

also often referred to as "soft spots," "porous," or "honey-combed metal," "sand holes," and "unwelded metal." It is in the nature of a breaking down of the tread into flakes or scales, by numerous cracks which

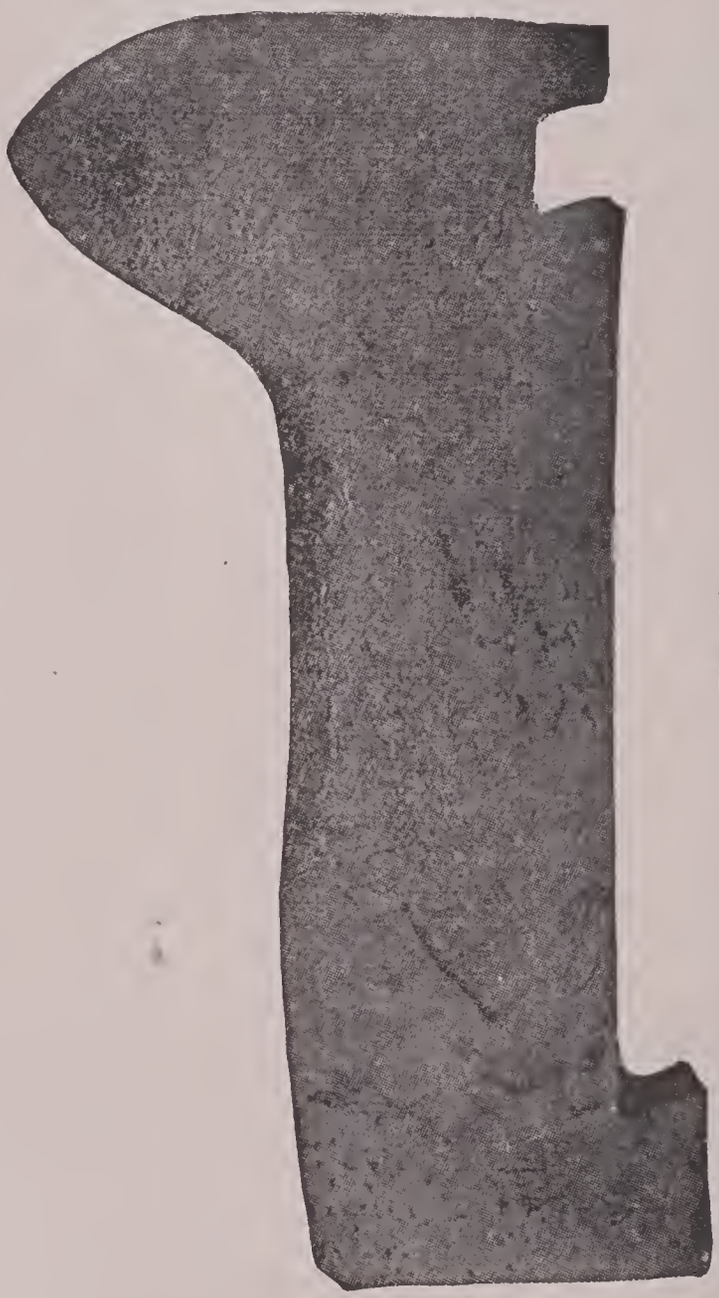


Fig. 11.

penetrate into the tire, principally in the area of rail contact. A tire developing such a condition is not considered dangerous, and consequently is not always

promptly removed. Hence the shells or flakes rapidly spread over a greater length of the tread, and the cracks penetrate so deeply into the tire that a large amount of steel is wasted in turning up the tire to remove all traces of the shelliness. Figure 13 shows the appearance of the tread of a typical shelly tire.

Fig. 12.

The causes which produce this condition of shelly or flaky treads may be inherent defects in the steel, such as pipe, gas cavities, slag and segregation, but are more commonly the conditions of service.

IMPERFECT TIRES CAUSED BY INHERENT DEFECTS IN THE STEEL

These are confined almost exclusively to tires made from short ingots and rarely occur in tires from long ingots, for the reason that the top portion of the ingot containing the pipe, slag, segregation and gas cavities, is discarded. The connection between the piping and

Fig. 13.

casting defects of the ingot and the shelliness of the tire is plainly shown in Figure 9. Usually the appearance of the tread of a shelly tire from inherent defects in the steel, is different from the ordinary shelliness due to service conditions. Instead of the tread showing spots with

numerous thin flakes, as in Figure 13, there is apt to be only a single spot from which a large shallow piece has spalled out, (see Figure 14), or there may be several spots where pieces have broken out of the tread leaving distinctly granular fractures, as in Figure 15. An etched transverse section of this tire, (see Figure 16), shows that these defects are due to entrapped slag.

Fig. 14.

IMPERFECT TIRES CAUSED BY CONDITIONS OF SERVICE

As has been stated, by far the greater number of shelly tires are produced by conditions of service, and in the case of tires from long ingots this is practically the

sole cause of this trouble. The conditions of service most prominent in causing shelliness are: Brake burns unequal diameters of wheels upon the same axle, which may result in causing the wheel to become eccentric through slipping; eccentricity of the wheel in its turn causing pounding. These conditions are all intensified by speed and load, but more especially by speed. It is probable that what is commonly termed "brake burn" is the chief cause producing shelliness. When the brake shoe retards the revolution of the wheel to the extent

Fig. 15.

that the distance traversed by the car exceeds that rolled by the wheel, a high degree of heat is generated locally on the tread, due to the slipping of the wheel on the rail. This results in the production of several small, hard slip spots, or brake burns on the tread within the limits of the rail contact. These small hard spots are usually covered with irregular heat cracks, which through the pounding of the wheel on the rail and joints, and under

the influence of various stresses to which the tires are subjected, tend to penetrate into the tire along the line of the resultant forces, causing the steel to break up into shells or flakes. In the case of chilled wheels the brake burns produce what is termed comby tread, and the penetration of the cracks is along the cleavage planes of the white iron crystals forming the chill, and perpendicular to the tread.

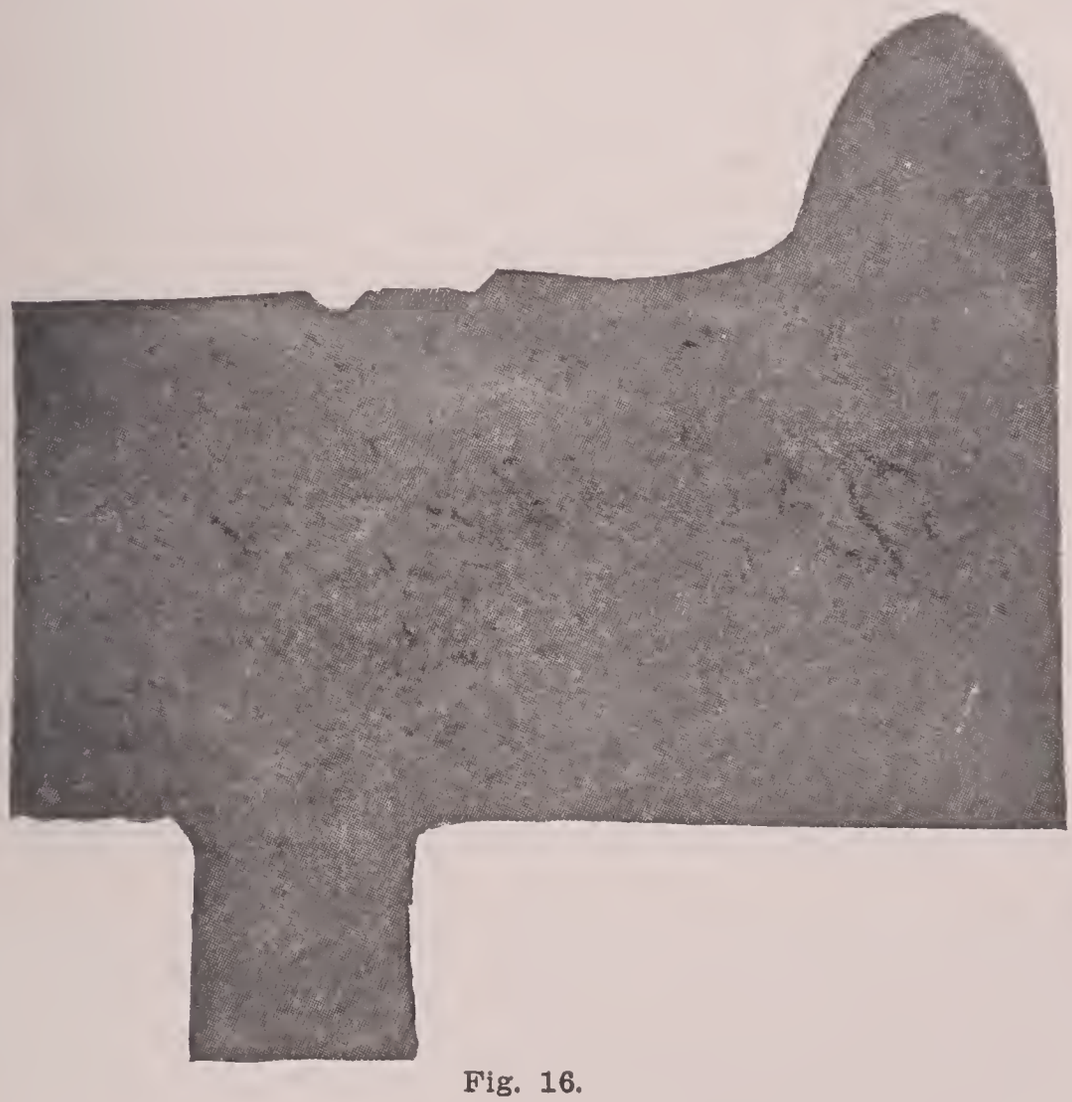


Fig. 16.

Many of the hard slip spots developed disappear through the friction of the tire on the rail, or under the scouring or tooling effect of the brake shoe, without

breaking up into shelly or flaky spots. In those cases eccentricity of the wheel results, and long, rolling flats are produced, sometimes 30 to 40 inches in length and as much as ½ inch deep at the lowest point. Frequently such wheels will have two rolling flat spots. The severe punishment through pounding and slipping which eccen-

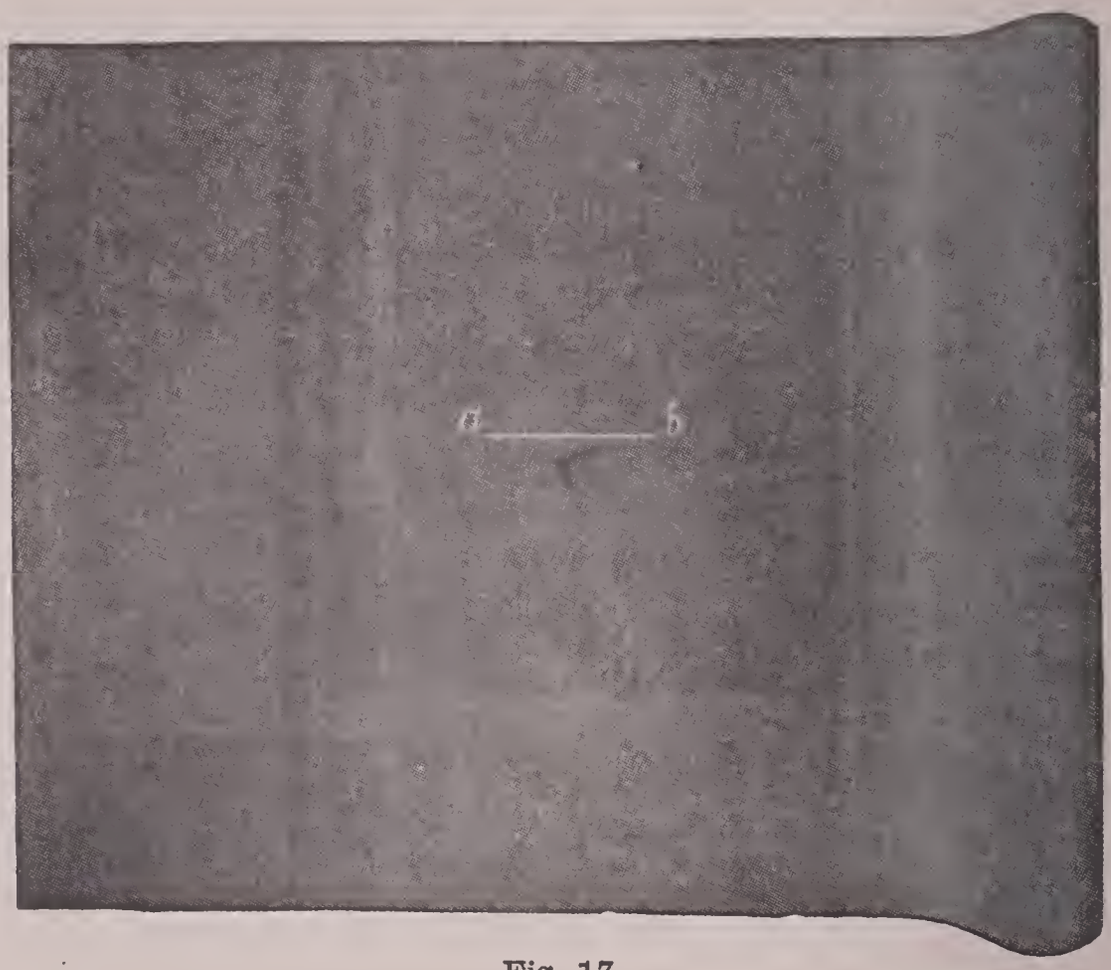


Fig. 17.

tric wheels undergo, produces excessive and deep shelling. That the wheels become eccentric or out of round through the hard slip spots has often been tested by putting a pair of wheels showing such spots but not shelled, into the lathe. It is not infrequent to find that the tool will skip for a space of two or three feet while cutting to a depth of 1-16 inch.

It is conspicuous that some of the roads having the greatest amount of trouble from shelly tread tires, find the trouble most serious on low grade divisions with infrequent brake applications, and on the heavy grade or mountainous divisions of these same roads the trouble is only slightly developed. This indicates that the long continued brake application on the heavy grades is effective in grinding off the small hard spots; or in other words, the tread is worn down faster than the rate of penetration of the heat cracks in the burned or slip spot area.

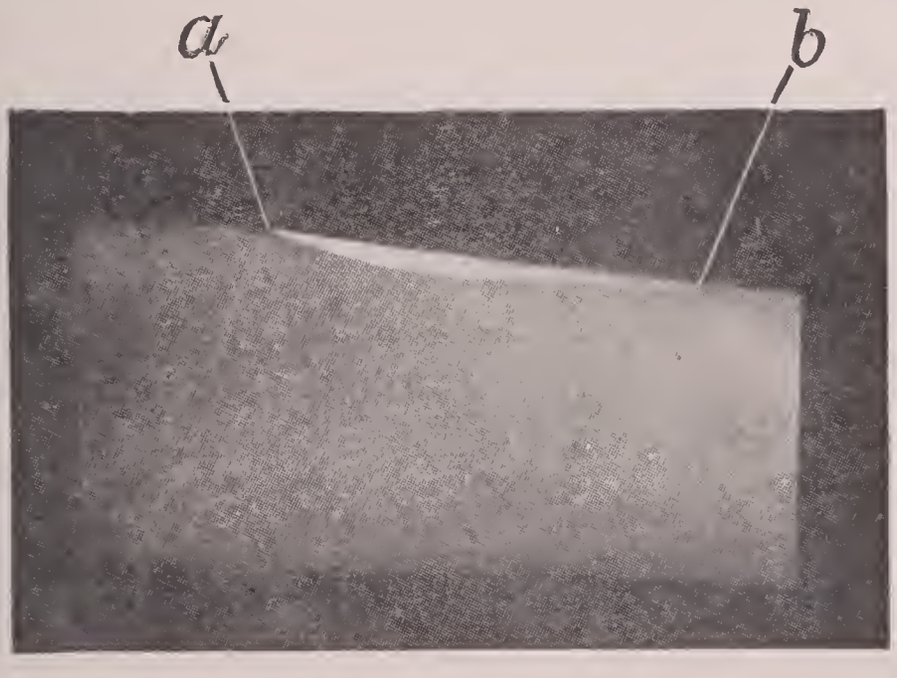


Fig. 18.

The formation of the shelliness from the hard slip spots, or brake burned areas is very well shown by the illustrations. Figure 17 is a view of a tire showing several of the brake burn spots, one of which has started to form a shelly spot. Figure 18 is a section through this spot on line *a-b* polished and magnified two diameters. The white area *a-b* is very hard and might be likened to

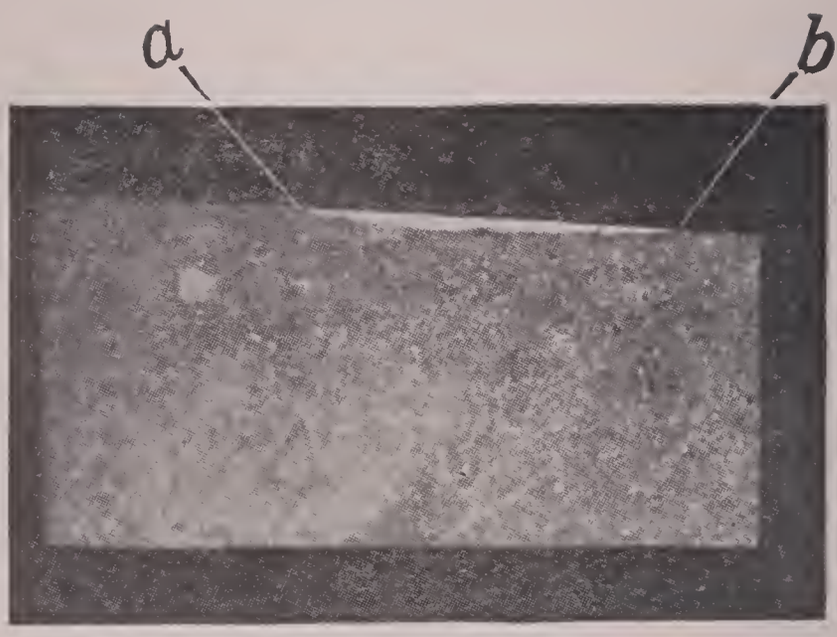


Fig. 19.

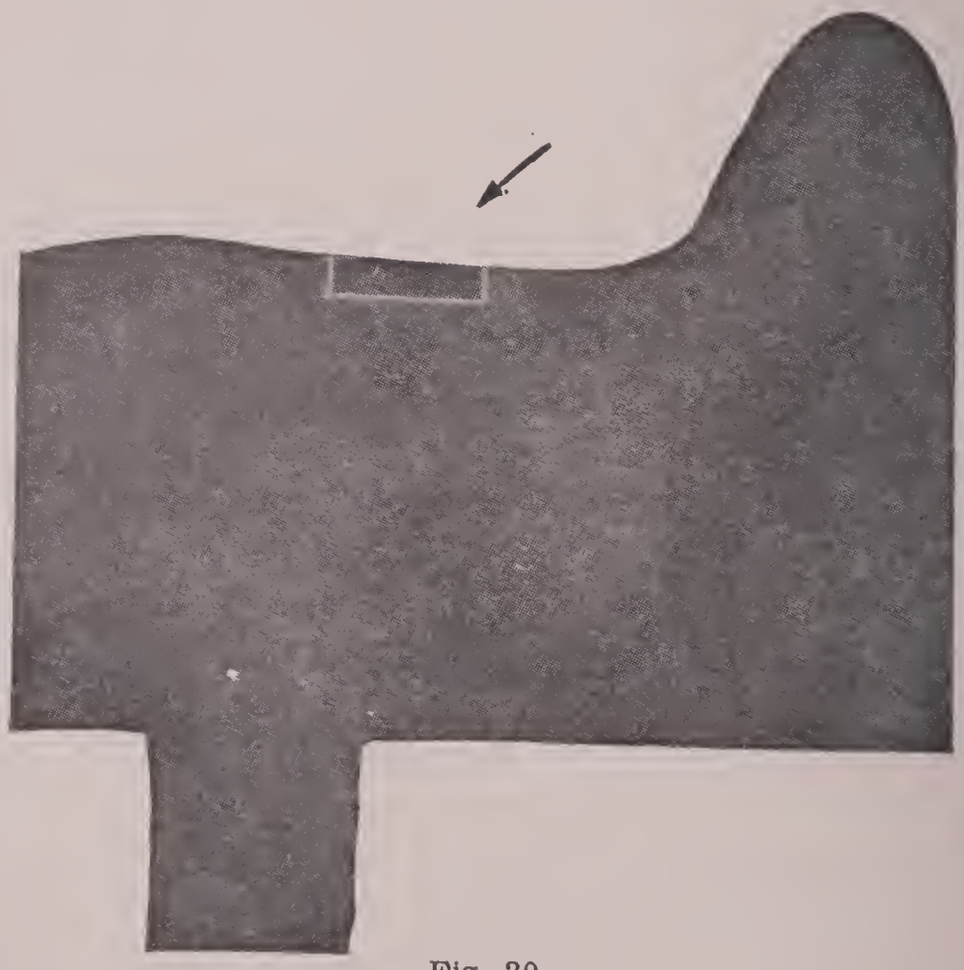


Fig. 20.

a case hardened spot. Figure 19 is a section through another spot on the same tire, polished and slightly etched to emphasize the contrast. It is the breaking up of these hard areas that originates the detailed cracks which penetrate into the tire and cause shelliness. Figure 20 is an etched section of a shelly tire, and shows no inherent defects. Figure 21 is a view

Fig. 21.

of the tread of the same tire which shows an advanced stage of shelliness. Figure 22 is a section cut from the tire as indicated on Figure 20, and polished and magnified forty diameters. It corresponds to the hard area shown on Figure 18, the letters *a-b* on Figure 22 marking the limit of depth of the hard spot. The metal between *a-b* and the tread shows a badly

cracked condition, and it is through the penetration and extension of these cracks that shelliness is caused and spreads as long as the tire remains in service after this condition originates. Figures 23 and 24 are etched sec-

Fig. 22.

tions to show the microstructure of Figure 22, magnified fifty diameters. In both Figures 23 and 24, the line *a-b* corresponds to *a-b* in Figure 22. In the case of Figure 23, which is located outside of the cracked or shattered

area, cleavage has not taken place along this line as is the case in Figure 24. The microstructure of the metal between the line *a-b* and the tread is distorted, but there is no tendency indicated towards separation of the micrograins along the lines of ferrite. This would be the case if the shelliness was commonly due to micro-

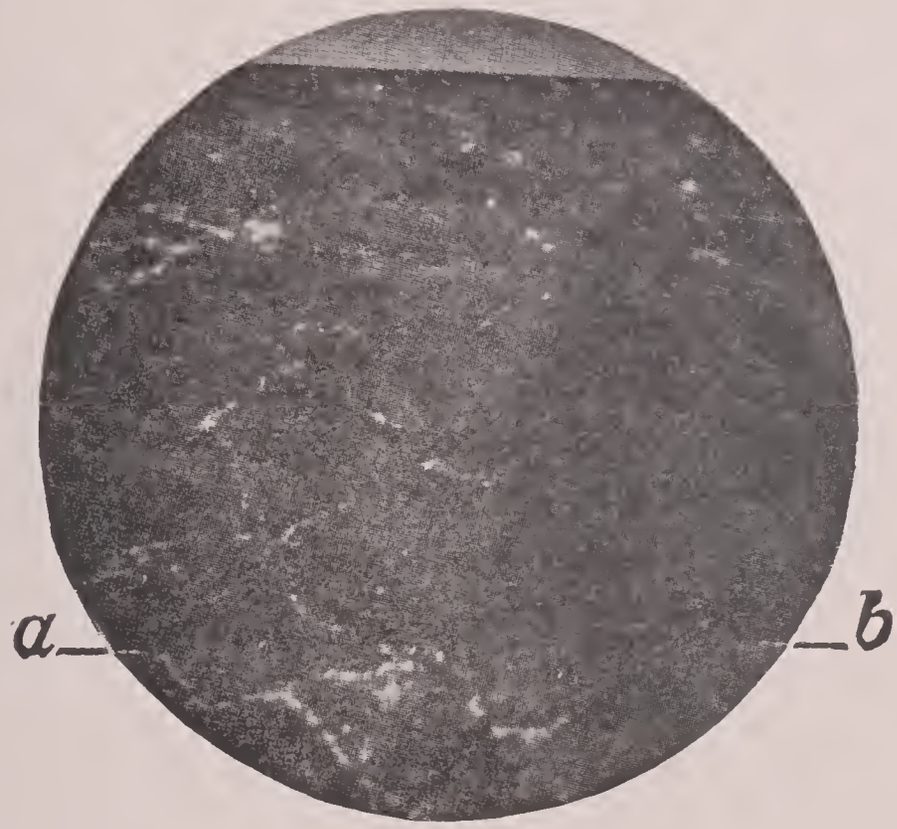


Fig. 23.

scopical particles or filaments of entrapped slag, as these usually occur in the ferrite. The microstructure below the line *a-b*, is entirely unaltered, and the line of demarkation is wonderfully sharp, cutting as it often does through the micrograins, and separating them into distorted and undistorted portions. Figures 25 and 26 illustrate clearly how these cracks extend and multiply. Figure 25 is a polished, but unetched specimen from a tire in the initial stages of shelling, magnified

thirty-five diameters. Figure 26 is a portion of the same specimen, etched and magnified fifty diameters. There is no evidence of any inherent defects. Figure 27 is a longitudinal section of a shelly tire and gives a good idea of the manner in which the shell cracks penetrate into and break up the steel. Neither this section nor the transverse section, Figure 28, show any inherent defects.

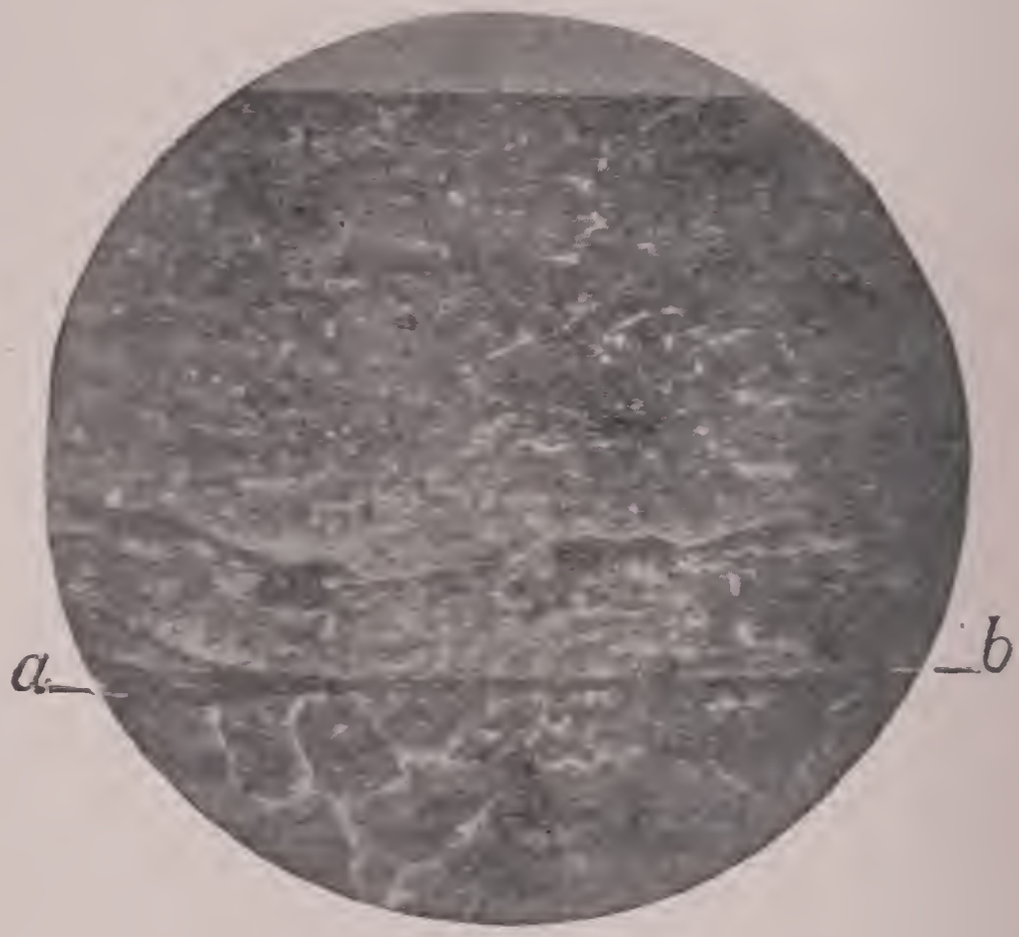


Fig. 24.

It is notable that driving tires are practically free from shelling, which certainly would not be the case if the shelliness was largely the result of inherent defects in the steel, improper treatment during manufacture, or defects of workmanship. The few cases of driving tires

which have been examined were due to inherent defects in the steel. Brake burns and slip spots are apparent on the tread of driving tires, but the rate of penetration of the cracks, owing to their greater diameter, and flatness of arc, is slow, and consequently their removal by brake wear is quite certain. Furthermore, the service conditions of driving tires are less severe than those of the

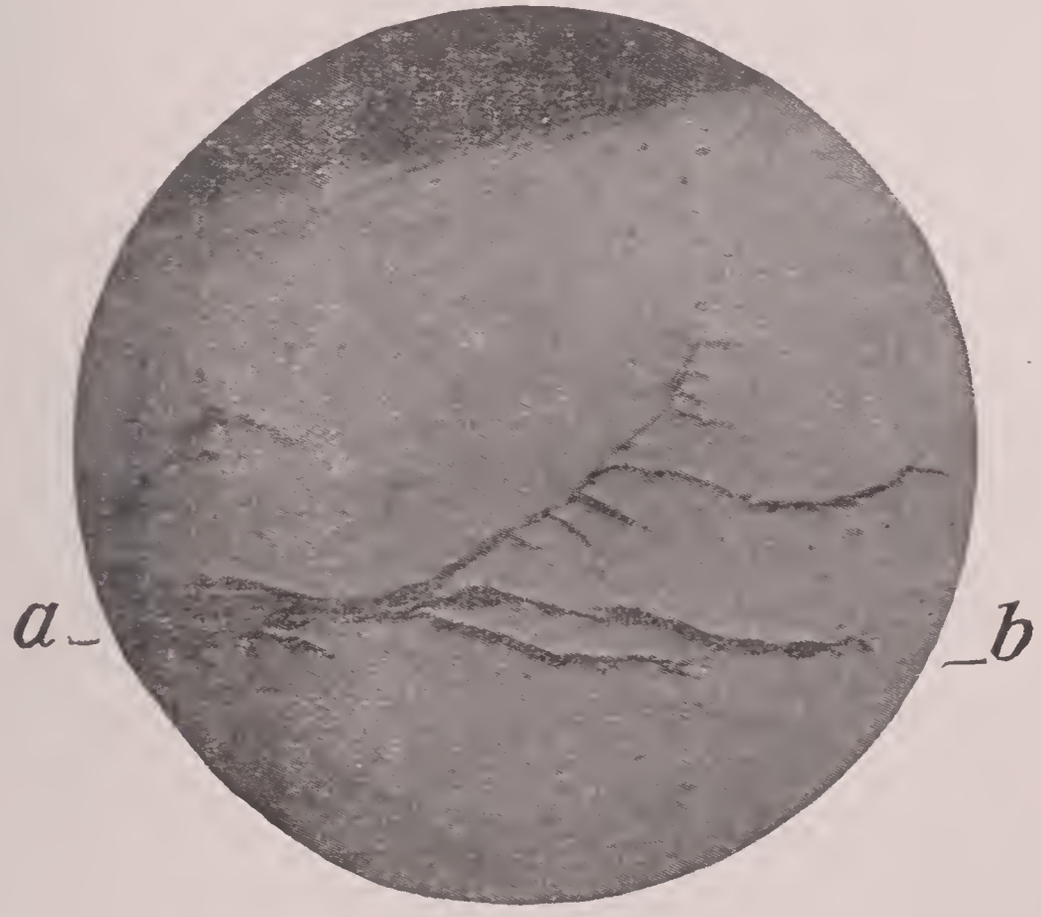


Fig. 25.

tender, trailer, and coach wheels. The number of revolutions is less, the area presented to the rail is greater, and the brake application is more effective. The static wheel load for driving wheels of modern high-class passenger locomotives averages about 22,000 pounds per wheel, while in the case of many trailing wheels and

wheels under large capacity tenders the wheel load is as great and is carried on a smaller area of rail surface.

The liability to shell is far greater in the case of tender wheels under heavy tanks in through passenger service than any other class of equipment. The service conditions of the tender wheels are the hardest of all the

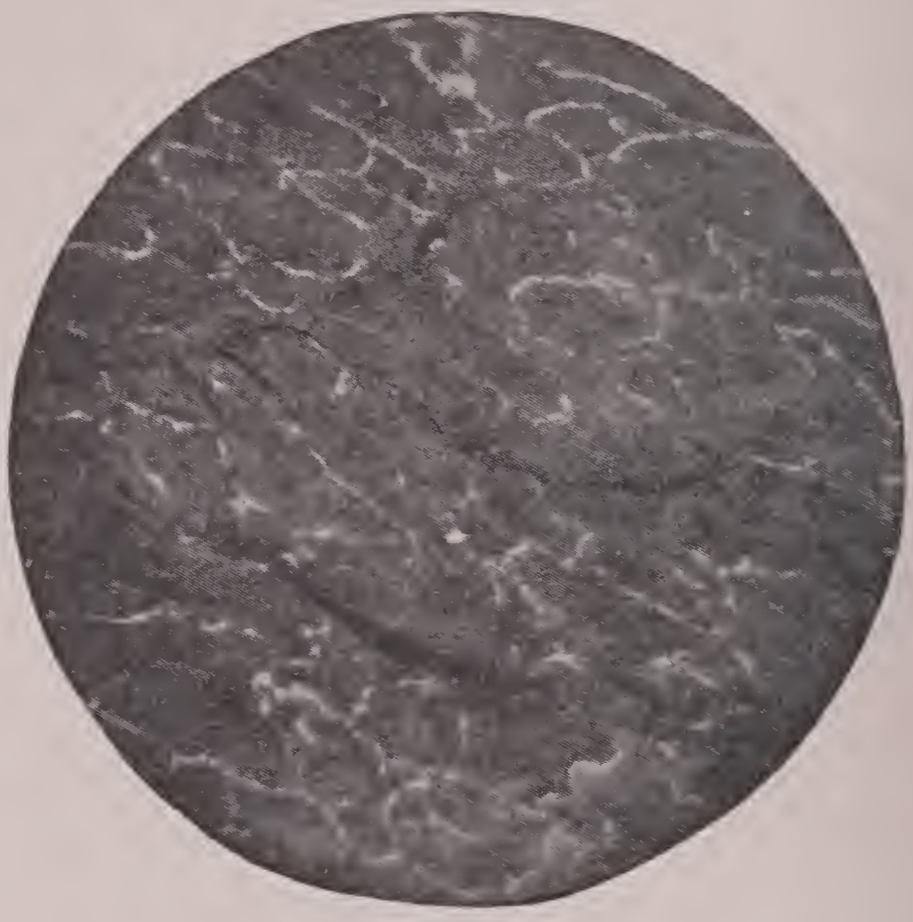


Fig. 26.

wheels, owing to the constantly shifting and varying load carried. The varying load not only affects the percentage of brake application, giving a variation in the retarding effect of the brake shoe on the wheels, and increases the liability to brake burn spots, but also causes the tender to ride rough and to pound the wheels. This is on account of the stiffness of the springs, which are

designed for full load, but carry a light load much of the time in service. There is a marked increase in the number of shelly tires during the winter season, which is natural, as all conditions of operation are more severe. In general the wheels under tenders do not receive the same attention as wheels under coaches. The inspection may be as close, but it has been observed that those roads having the most trouble from shelly wheels keep tender wheels in service that they would not tolerate under coaches. This observation is confirmed by the records of the wheel lathes which show an average of about twice as much metal turned off the tender wheels as from the coach wheels.

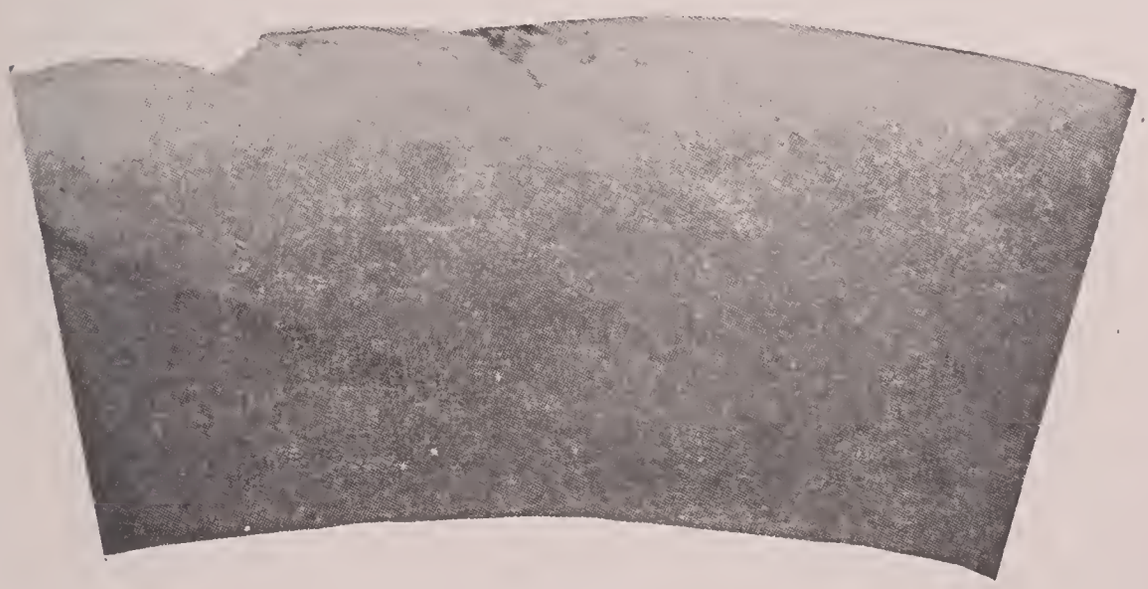


Fig. 27.

Trailer wheels probably rank next to tender wheels in tendency to develop shelliness. Most of the cases of shelly trailer wheels observed have been under engines in through passenger service, and the wheel load has averaged 20,000 pounds and upward per wheel. This great load, with the tendency of the trailer wheels to "pick up" on the application of the brakes and develop

brake burn spots is doubtless the reason why they have given so much trouble from shelliness.

Coach and engine truck wheels come next in order. Most of the shelly coach wheels have been under heavy cars in through passenger service. The majority of cases have been distinctly traceable to brake burns.

Fig. 28.

HEAT TREATMENT AND MICROSTRUCTURE.

The heat treatment of any piece of steel as evidenced by the microstructure, is important. Upon the proper heat treatment depends, first, the ability to produce the steel and second the quality of the steel. The phrase "improper heat treatment," however, has of recent years been much abused to explain "mysterious" failures. In

the manufacture of tires it is practically impossible to make a tire from an overheated or underheated ingot, as such an ingot would not withstand blooming under the hammer without failure.

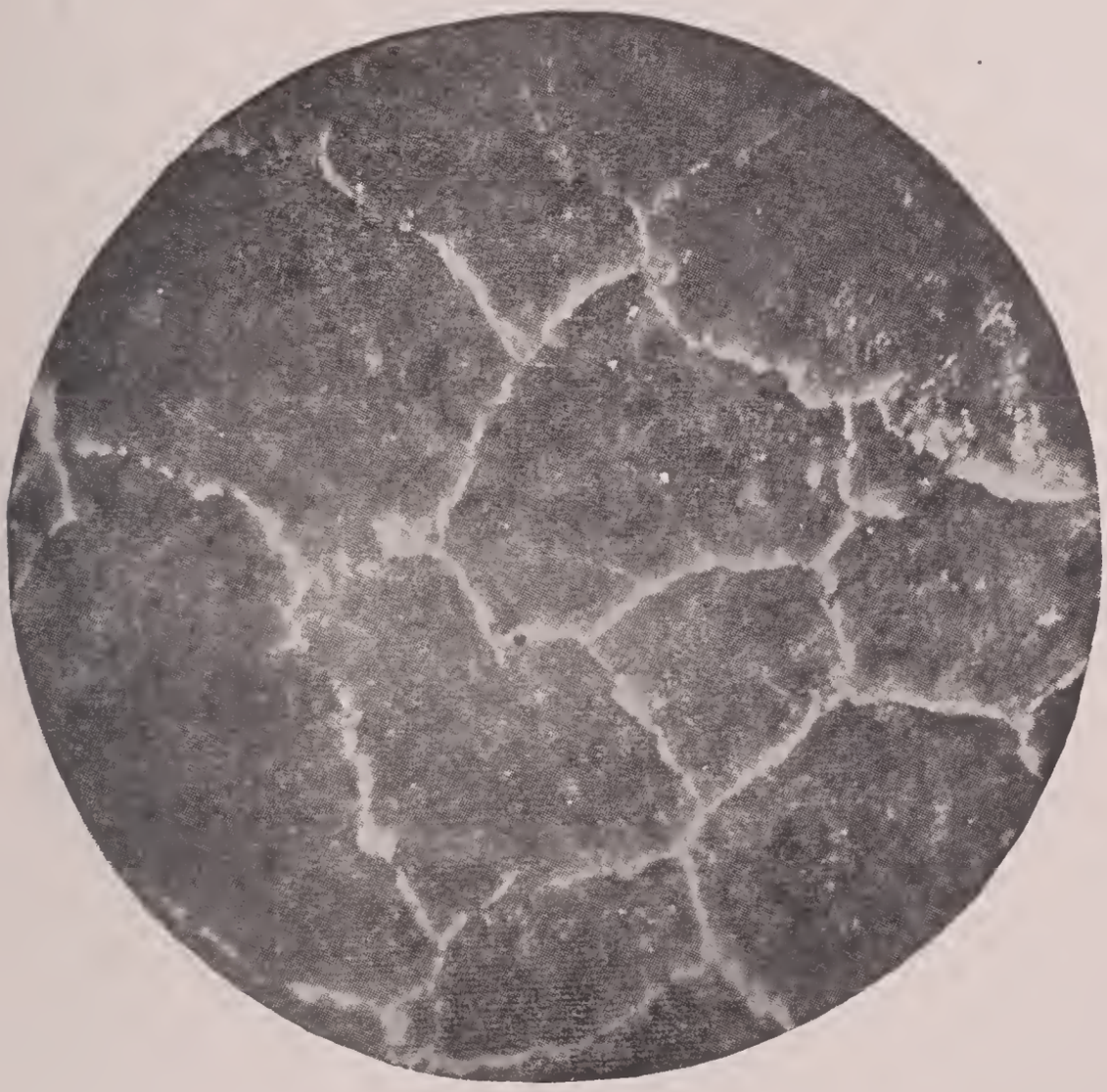


Fig. 29.

The examination of the microstructure of hundreds of discarded tires which have given good service shows what would usually be considered large grain structure. The natural micrograin of steels of the carbon percentage used for tires is quite large. To obtain a fine microstruc-

ture it is necessary to anneal the tires. This treatment however, has no effect in preventing shelliness. It is conceivable that under the heaviest wheel loads the annealed tire with the fine microstructure and large amount

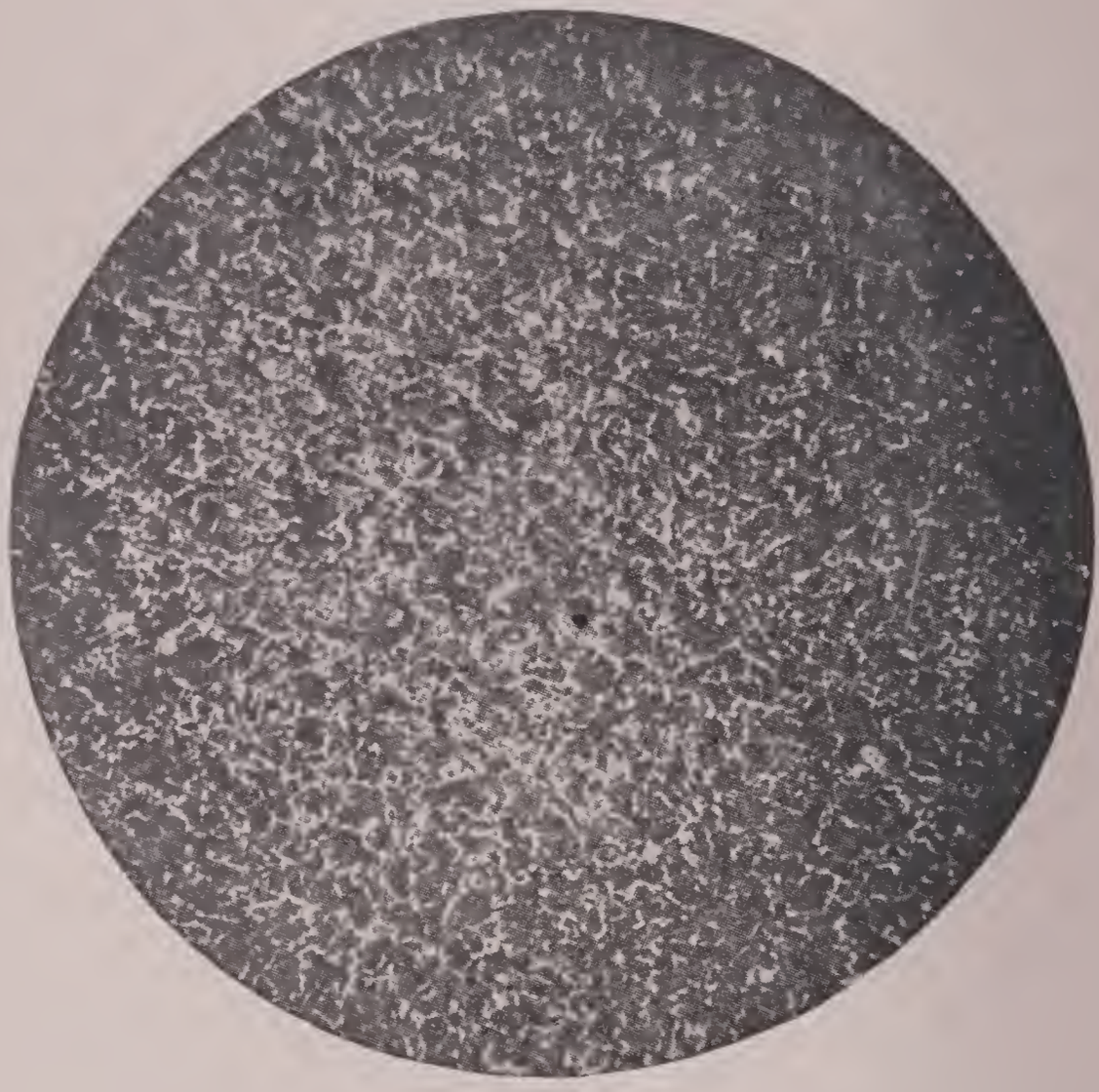


Fig. 30.

of isolated ferrite, or pure iron, would not give mileage results equal to the unannealed tire from the same steel, with its larger area of pearlite and greater resistance to distortion under compression. In the case of the comparatively large, natural grain of the tire as rolled, a

greater area of pearlite is presented for wear than in the case of the annealed steel, as is shown in the illustrations, Figures 29 and 30. Pearlite is the eutectic or saturated steel. It is composed of an intimate mixture of cementite (carbide of iron) and ferrite, (pure iron) usually in a lamellar structure, Figure 31. An ideal steel would be one whose structure is entirely made up of pearlite. Such a steel would contain about .85 per cent carbon, and would be too hard for most conditions of service.

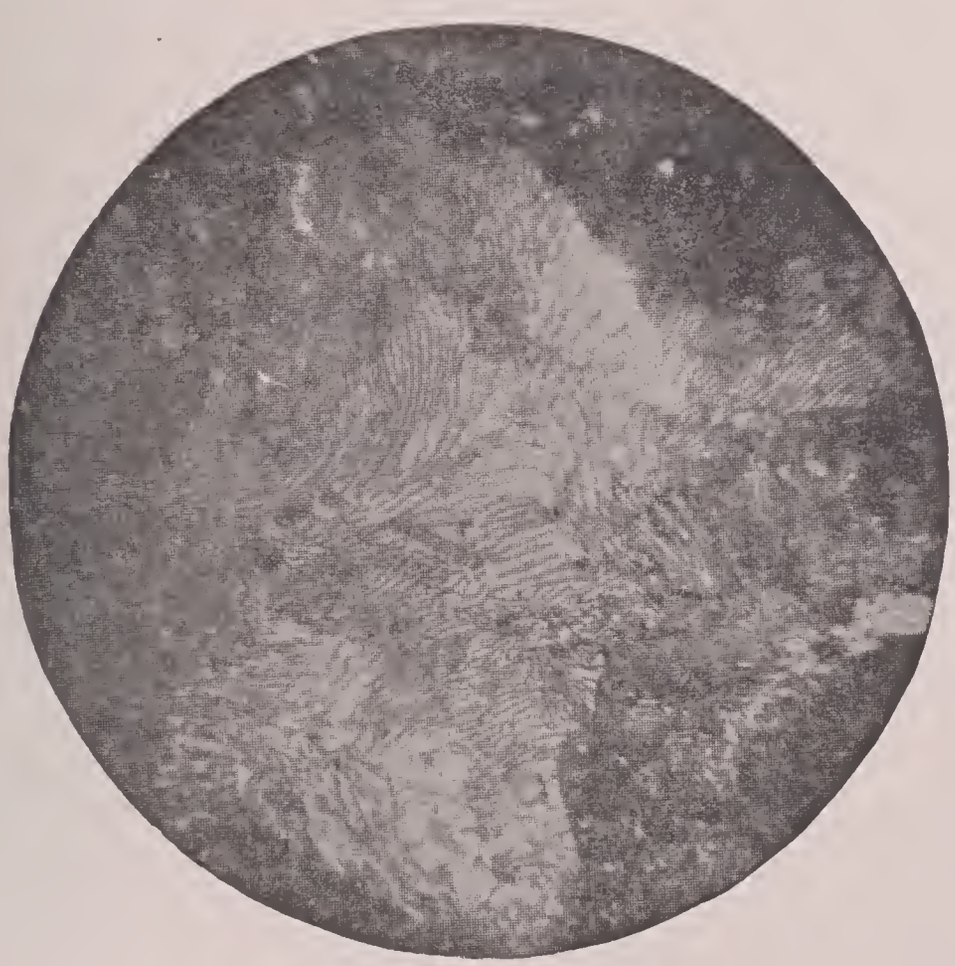


Fig. 31.

The macro or visible structure, rather than the microstructure, plays the most important part in the life of the tire. Unlike rails, and blooms, it is not possible to roll tires direct from the initial casting heat of the ingot,

consequently the ingot solidifies undisturbed by work under the hammers or in the rolling mill, and practically never shows the pronounced porosity so common in the center of the rail head. Working from a cold ingot which has solidified undisturbed, the maximum effect of the work under the hammer and in the rolls is obtained, increasing the density and homogeneity of the macro or visible structure.

CAUSES OF BROKEN TIRES.

The causes producing failures of this sort are: excessive shrinkage, inherent defects in the steel, transverse fracture of the flange, and loose tires.

EXCESSIVE SHRINKAGE.

Failures from this cause take place soon after application of the tire to the center, and always before the tire has had any appreciable service. After the tire has been in service a short time molecular readjustment has been completed in the form of motional annealing. This increases the ductility of the steel, as shown by increased elongation and reduction of area of comparative test pieces from tires from the same ingot before and after service.

INHERENT DEFECTS IN THE STEEL.

These defects are usually due to piping. In some cases the pipe is present as a cavity, Figures 32 and 33, which causes the tire to burst with a sharp transverse fracture. In other cases the pipe is present as in Figure

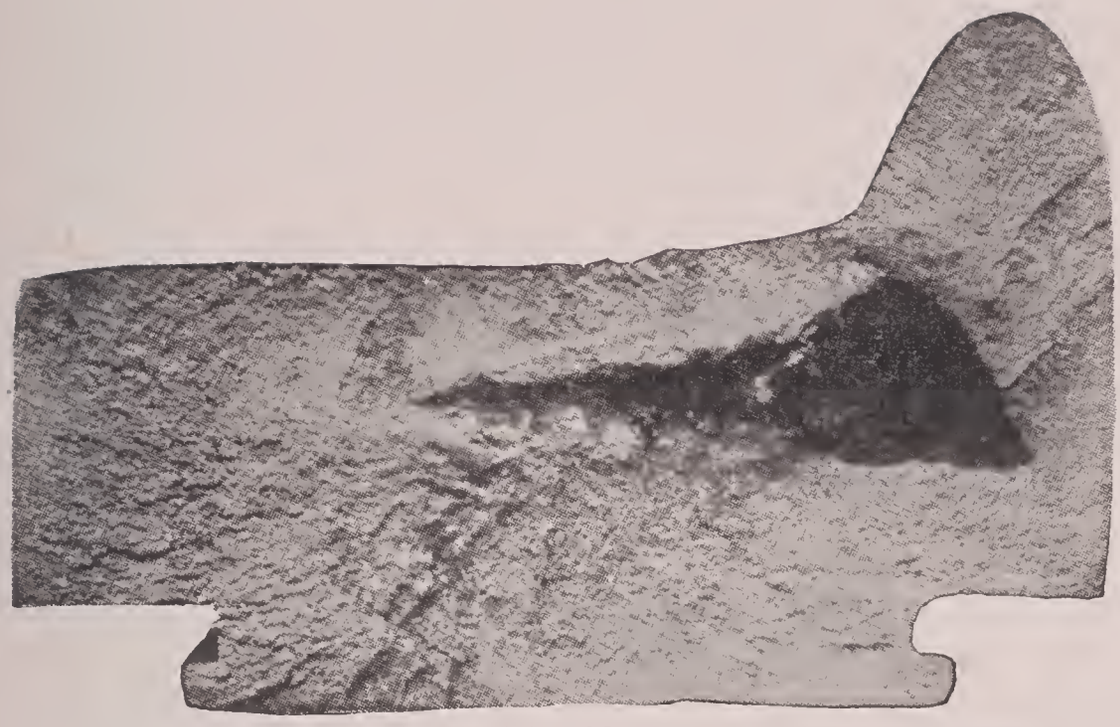


Fig. 32.

Fig. 33.

10, and then a piece of flange or tread is broken off. Tire failures from these defects are practically eliminated by the method of manufacture from long ingots.

TRANSVERSE FRACTURES OF THE FLANGES.

This is a detailed fracture originating on the point of the flange from heat cracks produced by the action of the overlapping brake shoe. Most of the failures of this kind have been tender and coach wheels in service over long heavy grades where the brake application is especially severe. It has been observed that wheels which have so failed are generally equipped with brake shoes without inserts. Such brake shoes generate much more heat on the flange than those with inserts, and are not so effective in scouring off the heat cracks formed by long continued brake application. In the case of the brake shoe with inserts in the flange groove, there is quite an effectual cutting or scouring out of the heat cracks and they are therefore less liable to start a fracture.

The illustrations Figures 34 to 40 show plainly the origin of the flange fracture from the heat cracks, and its development into a full fracture of the tire. Figure 34 is a view of a tire showing several small flange fractures, *a-b-c,* and their relation to the heat cracks on either side is obvious. Figure 35 shows a portion of the flange, full size, showing more clearly than Figure 34 the heat cracks with a fully developed fracture (*a*) in the midst of them. Figure 36 is a longitudinal section through the flange, line *a-b* on Figure 38, and magnified four diameters. This shows the depth to which pronounced heat cracks *a-a-a* will penetrate before developing a flange

crack. Figure 37 is a portion of the flange which has been polished and magnified fifty diameters and shows how the surface of the steel is broken up by heat cracks,

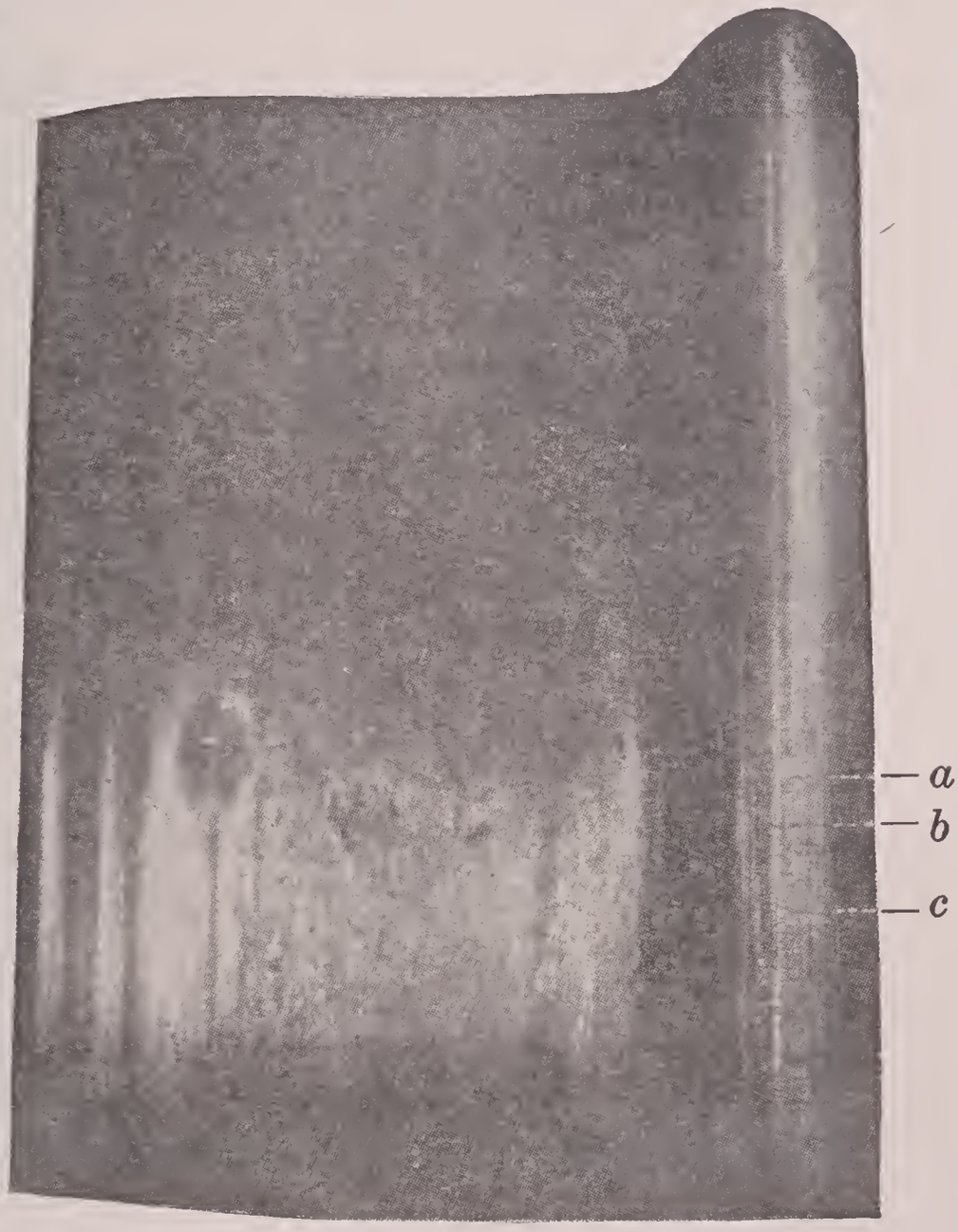


Fig. 34.

like sun-dried clay. The large cracks *a-a-a* are the transverse cracks from which the flange fractures originated, and correspond to those shown in Fig. 36. Fig. 38

is a cross section through the flange, magnified about two diameters, and lightly etched to show the depth to which the heating effect of the shoe has hardened the steel. This is shown on the illustration by the line *c*—*d*.

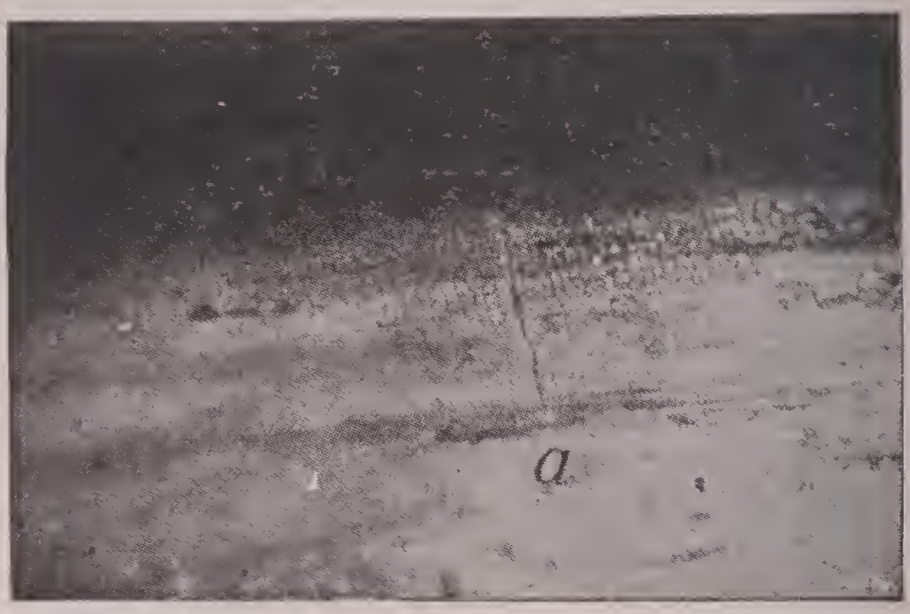


Fig. 35.

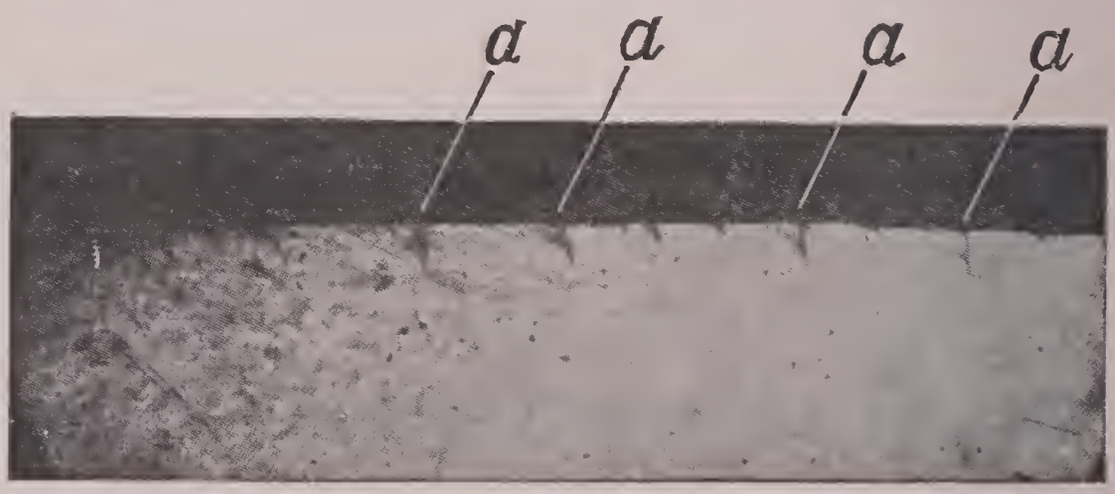


Fig. 36.

Figs. 39 and 40 show the fractured surfaces of two tires and the origin of the fractures is clearly traceable to a detailed flange crack. The extent of the crack before the tires broke is plainly shown on lines *a*—*b*.

Fig. 37.

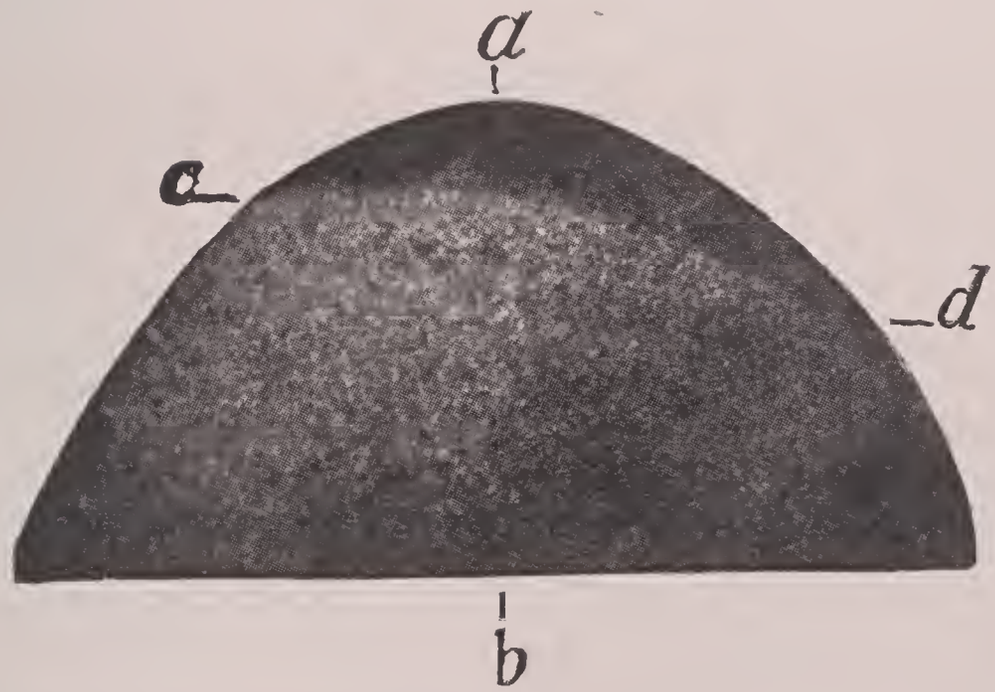


Fig. 38.

Broken driving wheel tires are found to have usually closely approached or passed the limit of road wear. In addition to failures from flange fractures originating from heat cracks, there have been quite a number of failures due to the lightness of design of cast steel driving wheel centers. On account of this lightness of design the tire has not a sufficiently rigid backing and when it begins to approach or reaches the usual limit of road wear the strains due to flexion of the tire are likely to cause failures.

Fig. 39.

LOOSE TIRES.

Breakages from this cause are confined usually to thin tires, and are due to detailed fractures, originating in the bore from repeated bending stresses. Fig. 41 shows the fracture of such a tire and how the fracture progressed by detail until only the light colored area remained when the break took place. Failures of this

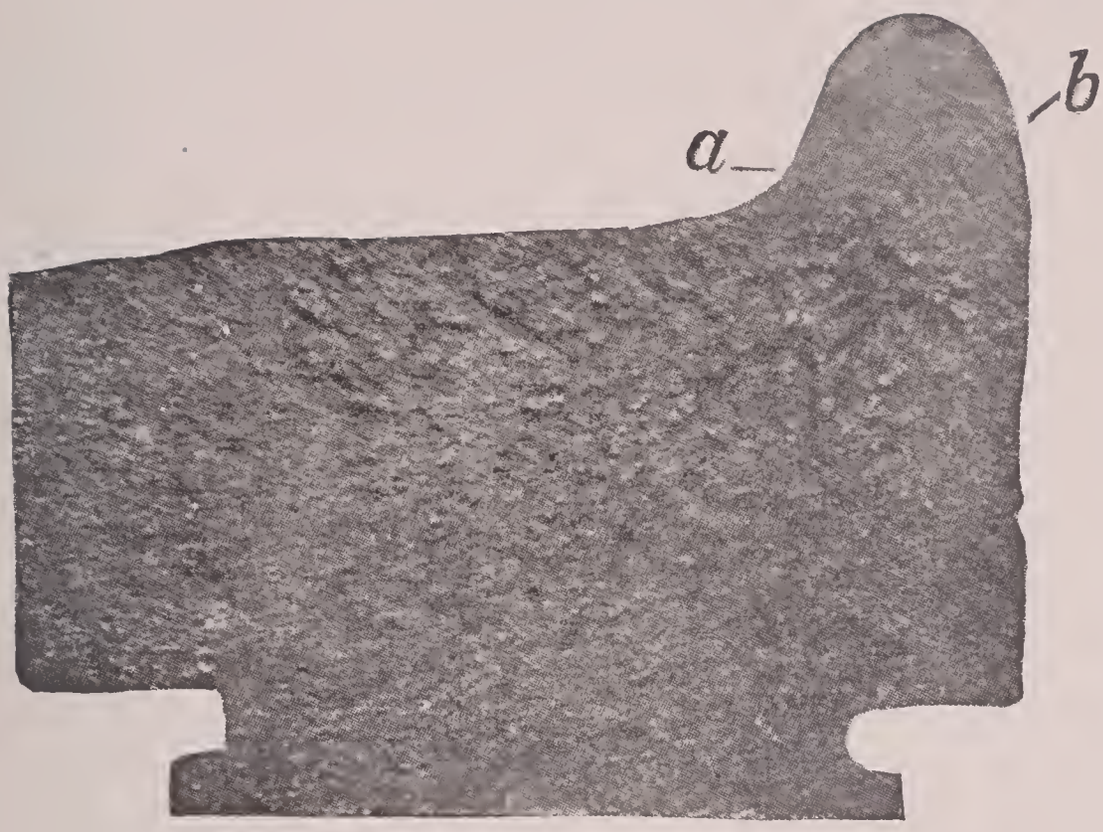


Fig. 40.

Fig. 41.

kind are not common as the tires are readily detected and are generally removed by the inspectors on account of being loose.

Remedy for Loose Tires.

Among the many troubles that beset the modern locomotive there are few that are more annoying than loose tires. They occur more frequently in summer as the heated rails tend to expand the rims of the wheels with which they come in contact more than the spokes of the wheels, which are to some extent kept cool by their larger exposure to the currents of air. When the tire slackens at a distance from the shop it is unsafe to proceed except at a very moderate pace, even if the wheels are furnished with bolts projecting through the wheel casting and set in a recess in the rim. The friction against the wheel flanges is so very great that a loose tire cannot be made to retain its position for any length of time if it has to depend on the points of two or three small bolts set at considerable distances from each other.

A temporary tightening can be made without removing the wheels if any means can be procured for heating the tire. In the absence of a gas or other regular tire-heater pieces of old rims or even bent pieces of rails may be heated and laid around the loose tire in such a way as to expand the tire sufficiently so that pieces of Russia iron cut into suitable strips may be inserted between the tire and rim of the wheel center.

It will be necessary to lift the wheel from the rail. This can be readily accomplished by jacking the axle and blocking between the binder and driving box. The operation will be facilitated by keeping the wheel as cool as

possible and heating the pieces to be applied to the rim as hot as possible. It may be necessary to loosen the main and connecting rods, but the operation has been successfully accomplished without disturbing the rods. It is advisable to have as many pieces of heated metal as can be applied to the tire at once so that the rim may be equally heated.

It is good practice in such operations to loosen the springs. A pair of screw jacks under the front and back of the locomotive will readily hold it in position. Any operation that involves the application of extra pressure to an individual spring is not good practice, the tendency being to over-reach its resiliency and thus sow the seeds of some future trouble. It is hardly necessary to add that the rapid cooling of the heated tire after the strips have been inserted is an important feature in the tightening of the tire, the slower that the cooling process occurs, the more likely is the tire to stretch sufficiently to bring on another attack of loose tire at an early date.

SQUARING THE VALVES WITH THE WALSCHAERT VALVE GEAR.*

First.—How can an engine with the Walschaert valve gear be squared up in the cut-off when she takes steam, say at six inches at one end of the cylinder and at eight inches at the other end, and different at each side of the engine?

Second.—How can an engine with Walschaert valve gear be squared up in the cut-off if she takes steam the same at both ends of the stroke, on both sides of the engine, but one side cuts off both ends at, say six inches, and the other side cuts off at both ends at eight inches?

Third.—How can an engine with Walschaert valve gear be squared up in the cut-off, at all, anyhow?

The third, and last, question is paramount, and a detailed answer to it will cover the other two. In transferring attention from the common link motion to the Walschaert valve gear, one should leave to the former type many of the cares incidental to its maintenance, and—if an engineman—forget many of the expressions used in allusion to the link motion, especially that one of "squaring the valves."

It should be understood, first of all, that the Walschaert gear contains no provision for adjusting the position of the valve, and is set up so rigidly at erection that if the valve works squarely when the engine comes from the shop, there are but three things that can cause any irregularity of valve action: one being distortion of the engine frame, or a general working out of line of the

*Will W. Wood.

parts that carry and support the valve gear; another cause is lost motion due to wearing away of motion pins and the bushings in which they work; and, of course, the only way to square the valves when they are out from those causes is to square up the whole engine, or supply new motion pins and bushings. But the very use of the Walschaert gear provides the room for extra frame bracing exactly where it is needed most, and the strains from strenuous service have the least effect on the frames of engines equipped with this valve gear; it is not found that the supporting pieces, brackets, etc., that carry the Walschaert gear work loose or get out of line. And as for slack in the motion work, the steel motion pins and their case-hardened bushings show so little wear between shoppings as to seldom need renewal when the engine is overhauled.

The third point of possible lost motion is, however, a probable one—the unpreventable wear in the driving-boxes—and this will produce irregularities in the motion derived from the eccentric. It is believed by many that there should be an easy way provided to lengthen or shorten the eccentric rod, in order to correct any errors in the motion of the valve due to wear in the driving boxes, after the wedges have been set up, but if no such provision exists the only remedy is the back shop.

The idea is that the Walschaert valve gear should be designed and erected correctly in the first place, and there can be no need, nor reason, for subsequently altering the action of the valve, but that as the true position of the main axle may vary from wear in the driving-boxes the length of the eccentric rod should be corrected to suit.

It may be, and is highly probable, that all of the irregular action mentioned by the correspondent in his first two questions could be corrected by changing the lengths of the eccentric rods, and it would be advisable to test them for errors.

Have the lost motion in the driving-boxes taken up as close as practicable. On the side to be tested first—the right hand side, preferably—place the engine with the crank-pins on the dead center—say the forward center—with the position fixed accurately; and it may be properly in order, here, to explain the method of setting an engine on the exact center: Secure a *tram,* or make a temporary one by taking a stick two or three feet long and driving a couple of sharp pointed nails through it, one near each end. Move the engine forward until the main pin is nearly on the center, and when the crosshead is within about one-half inch or so from the end of its stroke stop it there; now make a punch mark on some rigid part near the wheel—say on the wheel cover; set the tram with one of its points resting on the punch mark, and with the other point scratch a short arc line on the side of the tire. Without having moved the engine, now scratch a vertical line on the guide bar and crosshead in such a manner that if the engine should be moved you could reset the crosshead in the exact position in which it was when the mark was made, by simply bringing the lines on guide and crosshead into straight conjunction again. Then move the engine ahead *until the crank-pin passes the dead center,* and as the crosshead begins moving backward watch closely and stop it when the scratch marks on crosshead and guide are again in register, as explained. Once more take the tram and place one point in the punch mark on the wheel cover.

and scratch another short arc line on the side of the tire, as before; but although the crosshead was in the one location both times the tire was scratched, the marks on the tire will be some distance apart, and it is for you now to find with dividers the exact center between the two scratched arc lines; having done so, mark the point with a punch. The driving wheel must now be revolved backward to get the crank on the dead center, and having placed one point of the tram in the punch mark on the wheel cover, when the other point finds the middle mark on the tire—the one last made—the engine is then precisely on the center, on this side. When it becomes necessary to center the engine on the other side it can be done the same way, and the back centers may be found in similar manner.

With the main pin on the exact center on the side to be tested, have the reverse lever moved from the go-ahead corner notch up toward the center of the quadrant; while the link-block is rising, if the valve-stem is pushed forward, slightly, a cause for the error in the valve's action is indicated right there, and the eccentric rod should be *lengthened,* gradually, until the reverse lever can be thrown from one extreme end of the quadrant to the other—with the main pin on the exact center—without causing any movement of the valve-stem. On the other hand, if the valve-stem should be drawn backward by the rise of the link-block, the eccentric rod needs to be *shortened,* somewhat, until the full travel of the link-block from bottom to top of the link slot will not affect the position of the valve. Each side should be tested—and, if possible, adjusted—in the same way.

However, after the length of the eccentric rod has been so altered that with main pin on the dead center no

movement of the reverse lever can change the valve's position, if it should be that then the valve is not "square," there probably is a general distortion of the parts that carry the link and reversing shaft. Sometimes slightly altering the position of the link fulcrum by shimming between the link bracket and its bearer, or closing up, instead, will adjust matters; or, after the "set" of the link has been corrected by altering the length of the eccentric rod, errors in the valve action may be overcome by slightly lengthening or shortening the valve-stem.

A study of the general construction of the Walschaert valve gear will satisfy anyone that on a substantially built locomotive, with the gear properly designed and erected—and there is no doubt that every engine emerges from the builders' hands with valves as square as he wants them to be—the wear in service can have no effect on the set of the valves, except from the wear in the driving-boxes; and that if after adjusting the eccentric rods in the recommended manner the valves are still out of square, the proper remedy—and about the only one—is to *square the whole engine* in the back shop.

EFFECT OF REMOVING THE COMBINATION LEVER FROM THE WALSCHAERT VALVE GEAR.*

Referring to the "Questions and Answers on the Walschaert Valve Gear" in another part of this volume, directions for proceeding in case of a broken *combination lever,* are given in question No. 60. An engineer stated that whenever such an accident occurs on his road they never block the valve on that side of the engine;

*Will W. Wood.

that they simply remove the parts of the combination lever and the link that connects it to the cross-head at the lower end, then connect the radius rod to the valve-stem and go on with their train; that the engine works a little lame on that side—but that they "deliver the goods" at the terminal.

Owing to the fact that the Walschaert gear has been in use on American railroads for such a short time, and that there are no reasons why combination levers should develop a habit of breaking—I have never heard of a case except when the engine turned over, and she was towed in—I should hardly think that any road had experienced enough of such breakages as yet that they would have adopted any particular method for procedure, and especially have fixed upon one which may not always be possible, nor safe; and it must be conceded that the answer to question 60 represents a safe method.

Now, as a fact, the method of getting on as suggested by the correspondent is the best, and the correct way to proceed when the combination lever, or its link to the crosshead, is broken—if the valve should be an outside admission, D-slide valve—and if it is mechanically possible for an engineer to do it out on the road with the meager facilities afforded by the engine's kit of tools. I have never seen an engine on which it could be done—certainly there are none on the road with which I am connected, on which it would be possible away from the machine shop. An engine could be built with a view toward the possible necessity for connecting the radius rod with the valve-stem, and it is in evidence here that some are, but I have never seen such a design on engine nor blue-print. If, however, it may be done, what will be the effect?

Removing the Walschaert combination lever, and connecting the forward end of the radius rod directly with the valve-stem where outside admission valves, of the D-slide type, are used has the effect of *shortening the full travel* of the valve; with piston valves of inside admission, *their full travel will be lengthened.*

Either valve would maintain a position exactly one-fourth of the cycle of motion from the piston; when the piston was at either dead center point the valve would be unvaryingly at the middle point of its travel with both admission ports equally uncovered by the amount of lap, and both ends of the cylinder would be slightly, and equally, open to each other and the atmosphere by the amount of exhaust clearance, if such existed.

If the valve was of the D-slide type its action would be as though the engine was hooked up considerably higher on the affected side than on the side with normal motion. Steam admission would begin later and the port would have a lesser maximum opening—in fact, if the valve had a good deal of steam lap the reverse lever would not have to be hooked up so very far until the admission ports would fail to have any opening at all; and there would be no absolute *compression.* The engine would probably get along with a fair proportion of its rated load after once getting under headway.

Theoretically, it looks all right, the advice to establish a direct motion from the link-block to the valve when the combination lever has been broken off, and thereby be able to use a degree of the power on that side of the engine, and without the bother of blocking the valve. But advice on such points should be given only after studying every phase of the motion, for on a locomotive the motion work is often set up with a very close margin

for clearance between adjoining parts. As stated before, inside-admission valves—piston valves—would have their travel increased by removing the combination lever, etc.; now, as near as I am able to judge, a rather large per-

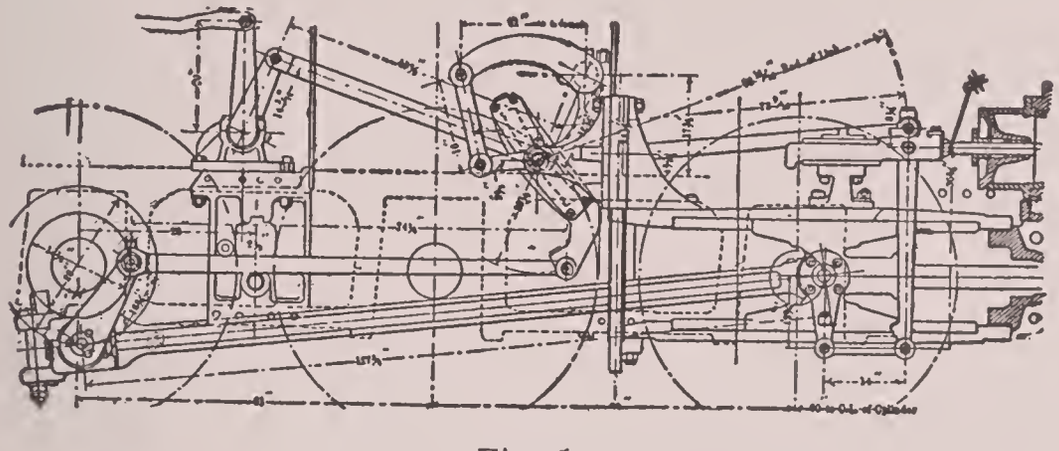


Fig. 1.

centage of engines built with the Walschaert gear have piston valves of inside-admission, so let us take up for investigation the consolidation freight locomotive built

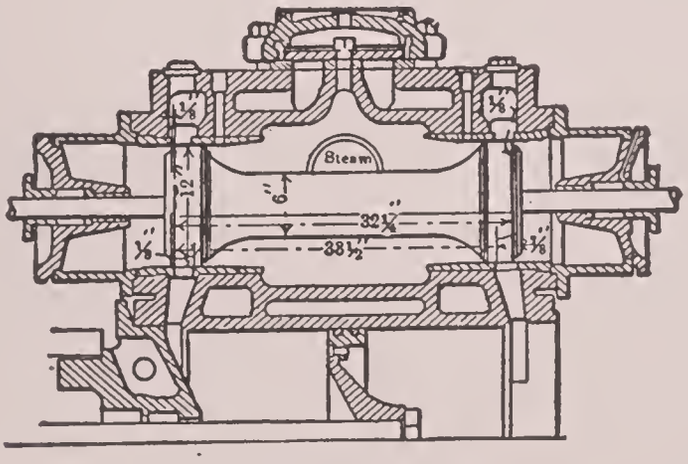


Fig. 2.

by the Baldwin Locomotive Works for the Pennsylvania Railroad, the motion work of which is shown in sectional side elevation in Fig. 1, and the inside-admission piston-valve in Fig. 2. The crank-pin is on the exact

quarter and that stations the *lower end* of the combination lever at its center of motion; the reverse lever in the center notch of the quadrant has fixed the link-block at the exact center of the link, and it, through the radius rod, has fixed the *upper end* of the combination lever centrally; wherefore, the valve is placed precisely at the center of its travel, the overlap of the admission ports being equal at each end, and the exhaust clearance also.

Let us now imagine that the combination lever is broken and we have removed it, and that we have succeeded in coupling the radius rod to the valve-stem. Take a pair of dividers and set the point of one leg on the center of the link-block pin, in Fig. 1, and the point of the other leg on the center of the pin in the front end of the radius rod, and let the dividers remain so set to retain the effective length of the radius rod. Then imagine that we throw the reverse lever to the forward, corner notch, thus dropping the link-block and moving the valve forward. Now, fix a spot in the link slot close to its lower end where you think the link-block pin would stand, clear down; mark the spot with a pencil and set the point of one leg of the dividers—*without changing their spread*—on this dot that represents the lowest position of the link-block pin, and let the other point rest on the center line through the valve-stem; mark, exactly, the spot thus found by the right-hand point of the dividers, for it represents the position of the pin that would join the radius rod to the valve-stem when the valve is at the forward end of its travel.

Again adjust the dividers, this time to cover the distance from the center of the pin that connects the combination lever with the valve-stem slide, to the point indicated by the double cross, "XX," which marks the end

of that part of the valve-stem that is free to work in the packing gland; the clearance distances are so narrowly defined that when the valve is at the extreme forward end of its travel the nut on the valve-stem at "X" will be very close to the face of the packing gland when the combination lever is in place and the valve gear working normally, and this last distance that we have found by the dividers is to prove that the nut referred to will strike the gland, and probably disable the engine, with the combination lever removed as was suggested. We had found the farthest point ahead where the pin would stand that should connect the radius rod to the valve-stem, and on this spot we set one of the points of the dividers, letting the other point fall on the center line of the valve-stem ahead, the dividers retaining their spread as lastly set, and the spot indicated now by the right-hand point will be where the valve-stem nut would try to get to in its forward travel, and will show that the gland would be encountered before the stroke was completed.

It is to be regretted that it is not always possible to proceed in cases of broken combination lever as advised by the correspondent. I believe it to be the fact that for engines of certain classes of service the combination lever could be dispensed with in the original designing of the valve motion, and with *a valve specially designed* in regard to the amount of lap on its steam edges and the determination of the exhaust openings, the engine would give a good account of herself; for it should be remembered that where an engine has but one eccentric, and it exactly 90 degrees from the crank-pin, the valve has an exceedingly quick motion while the crank is passing the dead-center points, and the maximum steam

pressure against the piston would be transmitted to the crank while it was passing through the degrees where it has the highest leverage power.

Two of the pamphlets that are issued by the American Locomotive Company every little while show types of Consolidation freight locomotives of their most recent construction, one of them illustrating engines of that class weighing less than 175,000 pounds, while the other pamphlet takes up those immense piles of machinery that weigh above 175,000 pounds—one of them weighing 250,500 pounds, and equipped with D-slide valves, too. It has been declared quite frequently that when large bearing surface was required of a valve working under a boiler pressure of from 200 to 220 pounds, it would have to be of the piston type; it seems, however, a mistaken theory; of the engines described in those pamphlets there are, of the lesser weights, 13 having piston valves and 17 with D-slide valves; while of the heaviest type noted, only 12 engines have piston valves and 16 have the D-slide valves.

For convenience and economy in operation, all engines equipped with the Walschaert gear should have slide valves. The link and link-block should be so constructed that when the radius rod is at the exact center of the link—reverse lever at the center notch of the quadrant—a smaller pin could be slipped through a hole in the center of the link fulcrum pin and through the center of the link-block pin, as the two pins of the gear are in perfect register with each other at this time, in this way making it easy to securely center the radius rod when disconnection is necessary, as in case of breakdowns; and a bracket should be attached to a point on the running-board or other convenient place to which

the front end of the radius rod could be pinned, raising it above all danger of interference after having disconnected it from the combination lever; this to facilitate getting on when it is considered necessary to block the valve; and it would be a first-class idea, too, when designing this gear for outside-admission valves, to so arrange it that the radius rod could be directly connected to the valve-stem, or its slide, and thus dispense with the necessity for blocking the valve under certain conditions of break-down.

THE ADAPTABILITY OF THE WALSCHAERT VALVE GEAR.*

"Of the many strong points in favor of the Walschaert valve motion, not the least by any means is the property of its adaptability without material change in construction to locomotives of odd design. In planning some of those multi-wheeled, monster freight engines to be equipped with the old, double-eccentric valve motion, it was a question of over-shortened, too sharply angular eccentric rods and a long, vibratory valve rod, or long, curved and vibratory eccentric rods and a short valve rod. And the space that the link motion had to occupy was needed for other purposes—frame bracing, for instance. The two engines of a big, modern locomotive, on opposite sides and working on the main axle just quartering to each other, produce such a distorting effect when laboring hard that it is no wonder *frame welding in position* is becoming common shop practice instead of an experiment. But frame breaking from

*Will W. Wood, in "Locomotive Firemen and Enginemen's Magazine."

service strains doesn't occur on engines with the Walschaert gear, because the gear is outside, where it belongs, and that leaves plenty of space for strong cross-bracing of the frames at the vital point, and which is taken advantage of. And being outside, there is nothing to interfere with the arrangement of the Walschaert gear, except the 'clearance limit.'

"It doesn't matter what the type of engine, the Walschaert gear is included within the distance between the main crank-pin and the crossheads of piston rod and valve-stem, and there is nothing in the way of putting it there. The main driving wheel is always at about a certain distance from the cylinder, and as the length of main rod limits the distance that the valve gear must occupy no extension pieces are necessary—no transmission bars, etc.—with the Walschaert motion, one of the reasons for its adaptability.

"But it goes still further: I want to call attention to the general adaptability of this valve gear with direct reference to the big Mallet Articulated Compound engine recently built by the American Locomotive Company for the Erie Railroad, and which was illustrated and described in this Magazine in the issue for last October; preliminarily, it may be to the benefit of those who have not given the principles of the Walschaert gear very much attention to explain a few things in connection therewith.

"So far it has been the general practice in America to so design the Walschaert valve gear that when the reverse lever is carried in the forward notches of the quadrant—go-ahead position—the radius rod and link-block work within the lower half of the link, and hooking-up the engine in forward gear is the correct expres-

sion literally, for it *raises* the radius rod. Fig. 1 represents in diagram this method of construction in connection with a valve of outside admission—the common D-slide valve. As the sole duty of the combination lever is to advance the movement of the valve the distance necessary to offset the lap and provide the partial port opening for lead, when lead—meaning pre-admission—is required; to do this with outside admission the valve must be advanced in an opposite direction from the piston, so the valve-stem is connected to the extreme end of the combination lever, advancing the valve *from* the piston, always, with the piston at either end of the cylinder. With inside admission valves, the radius rod is connected to the extreme upper end of the combination lever, with the valve-stem connection beneath it. These are fundamental and unchangeable rules that must be observed in designing or erecting the Walschaert gear regardless of any strange or special arrangement of the other parts of the valve motion, and in the case of piston valves is the sure way of determining whether the valve is of inside or outside admission when you are inspecting a strange engine.

"With the ordinary arrangement of the gear in general, as shown in Fig. 1, the eccentric goes a 'quarter' ahead of the main crank-pin (presuming the wheel to be revolving forward), and this is commonly supposed to be a fundamental feature also, but it is not; the eccentric is simply placed at that point to conform to the effect of running with the radius rod at the bottom of the link in forward gear. Suppose that we should change the position of the eccentric of the engine of Fig. 1 to a point exactly opposite—just a quarter *behind* the main pin; the effect is simple: the valve would be given an

exactly opposite motion to that it should have to cause the engine to run forward, with the reverse lever in forward gear. On the other hand, leaving the eccentric as it is in Fig. 1, suppose we should change the revers-

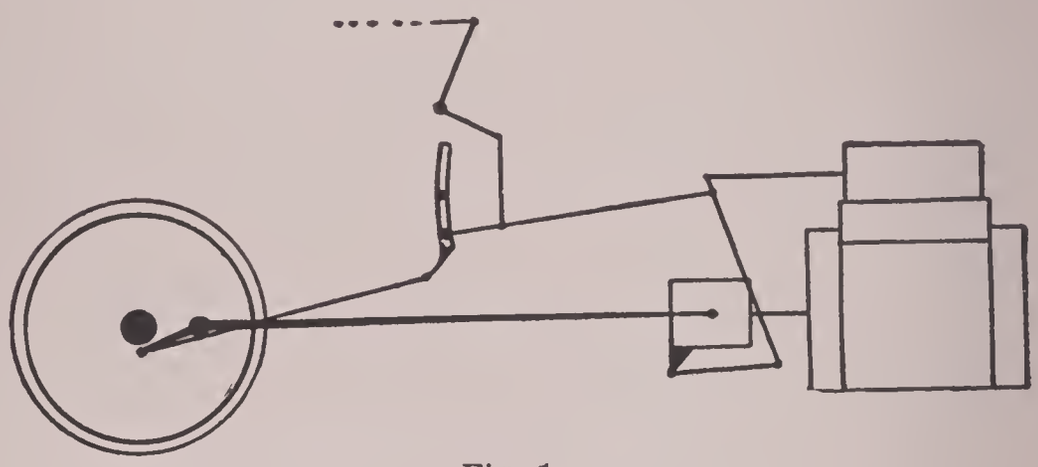


Fig. 1.

ing arms, so that with the reverse lever in forward gear the radius rod and block would be carried in the *upper half* of the link; simple again, and like the preceding

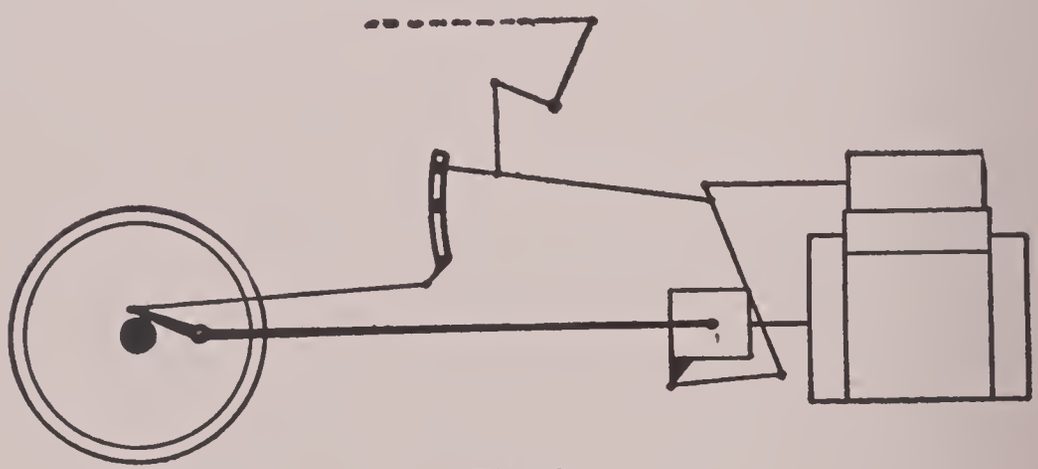


Fig. 2.

case of shifting the eccentric, the valve would be given an exactly opposite direction of travel to that it should have in the forward gear. And with the reverse lever in a back-up notch, these changes in eccentric and radius

rod location would have a similarly contrary effect on the travel of the valve.

"Now, if 'two negatives make an affirmative,' likewise we can, by mutual changes, oppose those contrary effects against each other without introducing any irregularities in the valve motion. So, in Fig. 2, we have the engine with outside admission valves with which it is found necessary, for some sufficient reason, to run with the radius rod above the link center in the go-ahead position, and below the link center when backing-up; the reverse gear has been so designed, and in order to rectify the counter-motion implied by this change it will be noticed that we have shifted the eccentric 180 degrees—placing it a quarter *behind* the main pin. Such alterations have no effect whatever on the lead, for the eccentric plays no part in establishing the lead; that, as explained before, is the exclusive business of the combination lever.

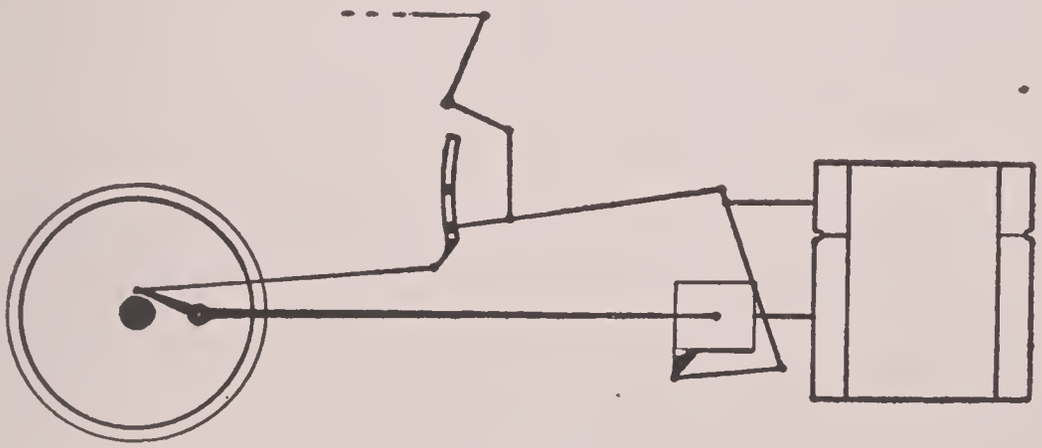


Fig. 3.

"In Fig. 3 we have the most common American style of arranging the Walschaert gear with which inside admission (piston type) valves are used. In this case, to secure lead the valve must be advanced *toward* the piston, so the valve-stem is connected to the combination lever

at a point *below* the radius rod, and this gives the admission opening from the inside of the valve. The radius rod, in forward gear, is carried in the lower half of the link, and to give it the required direction of motion the eccentric follows the main pin by a quarter. However, with this valve of inside admission, suppose we want to reverse the regular plan and run with the radius rod in the upper half of the link in the forward gear; we make the change, and in compensation therefor we simply shift the eccentric from its original position, a quarter behind the main pin, as in Fig. 3, to the point directly opposite

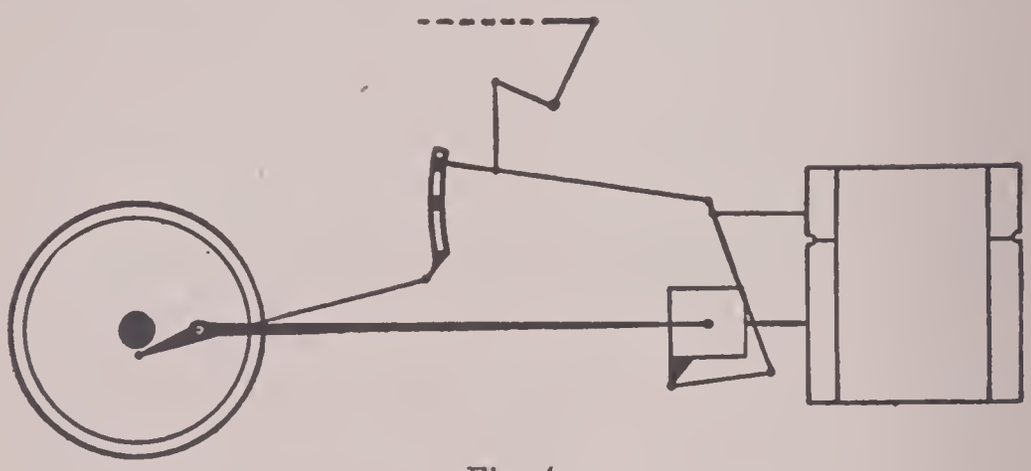


Fig. 4.

—a quarter *ahead* of the main pin; and Fig. 4 is the diagram of the gear so changed in full, and correct. We have found that it is possible to carry the radius rod at either the top or bottom of the link, for either go-ahead or back-up position, with either inside or outside admission valves; it simply involves changing the location of the eccentric in reference to the position of the main crank-pin.

"Fig. 5 is the side elevation of the Mallet articulated engine of the Erie Railroad, referred to. There are really two distinct engines on each side, entirely separate

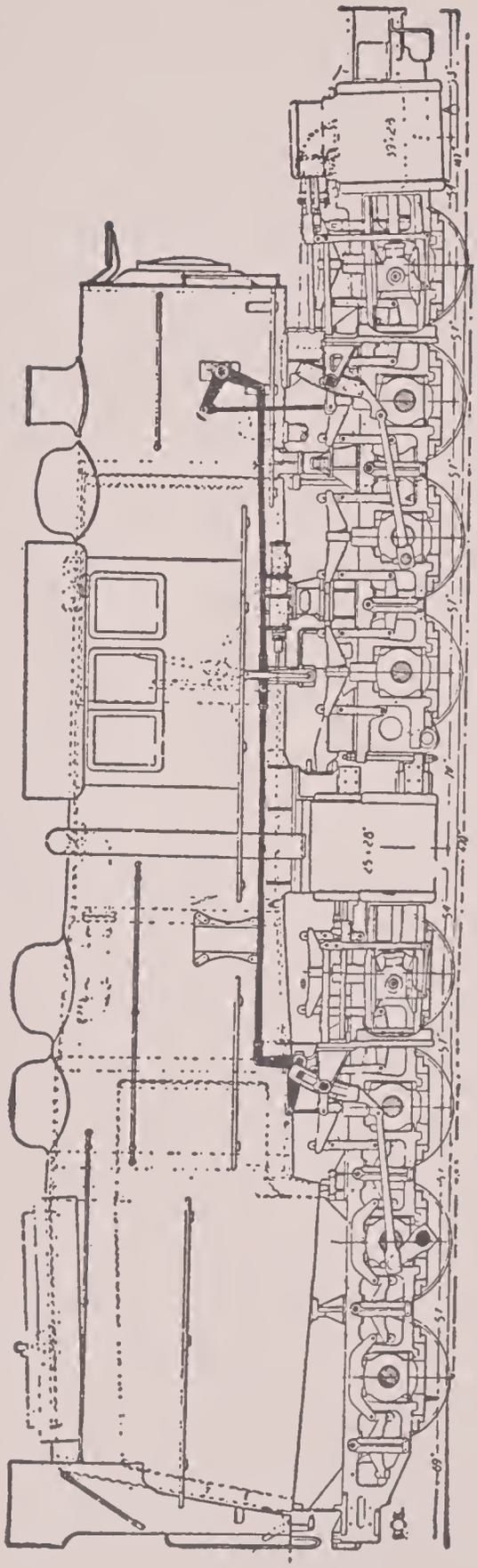


Fig. 5.

from each other in action except that when working on the compound principle the front engine uses the exhaust steam from the rear engine; of course, in starting a heavy train or to prevent stalling on a hard pull, boiler pressure may be admitted to all cylinders of the locomotive. The rear, or high-pressure, engine has piston valves of inside admission, while the front, or low-pressure, engine has slide valves, and, of course, such are always of outside admission.

"The motion work of this locomotive is so arranged that when the radius rod of the front engine is below the center of the link the radius rod of the rear engine is above the link center, and *vice versa*. To get correct results from this arrangement, the motion work of the front engine is designed on the very principle that is diagrammed in Fig. 1, and the design of the rear engine corresponds exactly with the diagram in Fig. 4. The depression of one set of gearing counter-weighting the elevation of the corresponding set on the other 'engine,' has a nice balancing effect on the reversing mechanism. In Fig. 5 the outlines of the reach-rods, reversing and lifting arms, and suspension bars, are filled in in black for particular notice. The crank-pins of the forward engine are not shown, but, as the locomotive stands, the crank-pins of both front and back engines are on the lower quarter, corresponding with the position in which the main crank-pin of the rear engine is shown.

"This particular engine of the articulated, compound type affords one of the very best studies of the Walschaert valve motion in general, as well as it illustrates the adaptability of this valve-actuating gear to locomotives of particular and peculiar design."

WALSCHAERT'S VALVE GEAR AND BREAK-DOWNS.

The Walschaert valve gear shows a distinct advantage over the Stephenson link motion as regards permanence of adjustment, says Mr. C. O. Rogers, Traveling Engineer, American Locomotive Co., who states that, "when a large freight engine is half way between shoppings the Stephenson link motion is slack and loose, while the Walschaert valve gear is in as nearly good condition as when the engine left the shop; consequently the original steam distribution is much better maintained with the Walschaert than with the Stephenson motion.

"These are some of the reasons why a large number of American railroads are now equipping their engines with the Walschaert valve gear. Seldom in the history of the development of the locomotive in this country has any improvement, once introduced, been so rapidly accepted as this type of valve motion; and, inasmuch as its use will undoubtedly increase, a clear understanding of its principles and construction is essential for all those who operate engines so equipped.

"The best place to begin is always at the beginning; and as the Walschaert valve motion, like any other device, is merely a development of some simpler form, it is necessary in studying it to start with the original form and trace the various steps in the development.

"Fig. 1 represents the simplest form of valve motion; viz., a single eccentric of the return crank form, driving a plain normal valve without lap or lead by means of an eccentric rod directly connected to the valve stem. Assuming that the engine is to run forward, with the main

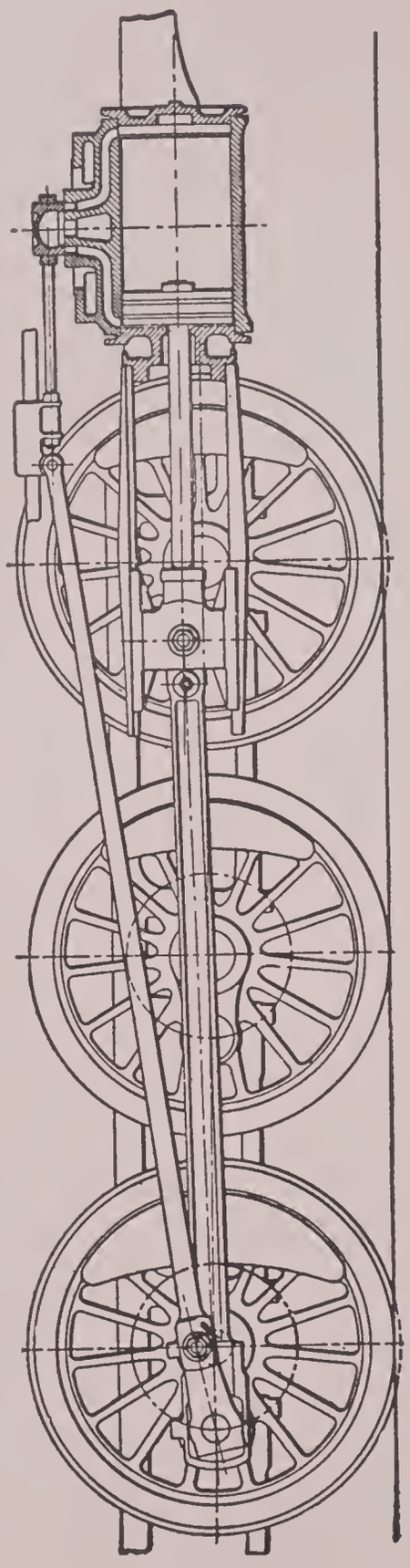


Fig. 1.

pin on the back center, as shown, the eccentric crank pin must be on the top quarter; in which case the valve will be in the central position on its seat with all ports closed. Although it is apparent that if the throttle were open this engine could not start of itself, with another engine of the same kind connected to the wheel on the other side of the axle, and with the main pins at right angles to each other, as is the case in the locomotive, the valve of the left hand engine would be in a position to admit steam behind the piston and start the wheels turning to the right. The eccentric crank on the engine which is shown would then move the valve forward, uncovering the back steam port and admitting steam behind the piston, and the engine would run forward. It is perfectly evident, however, that this engine will only run in one direction; for if, to start it backward, the wheel was pinched to the left, with the eccentric in the position as shown, the valve would be moved to the left and steam admitted ahead of the piston, forcing the crank pin back again to its position on the back center. In order to make the engine run backwards, the eccentric would have to be in the opposite position from that which it occupies, or on the lower quarter; in which case as the wheel was turned to the left or backward the eccentric would be a quarter of a revolution ahead of the main pin and move the valve forward, opening up the back port and admitting steam behind the piston as is necessary.

"The first thing to do in the development of this simple form of engine, therefore, is to introduce some means by which it can be reversed. This can be accomplished by introducing a beam between the eccentric and the valve stem, pivoted at its center so that one end moves with

and in the same direction as the eccentric and the other end in exactly the opposite direction.

"Such a construction is shown in Fig. 2. With the valve stem at the lower end of the link and the main pin on the upper quarter, as shown in diagram 'A,' the eccentric will have moved the valve to its extreme forward position and the back port will be opened for the admission of steam behind the piston and the engine will run forward. If, however, with the main pin and eccentric crank in the same position, the valve stem was connected to the upper end of the link, as shown in diagram 'B,' the valve would be moved to its extreme position to the left and the front port would be opened and steam admitted ahead of the piston and the engine would run backward. With a flexible valve stem, or radius rod, connected to a block which slides in a curved slot in the beam, or link, as shown, and with the necessary mechanism for raising and lowering the block, it is evident that we now have an engine that can be reversed.

"This engine, however, is still far from an efficient machine; for, as the valve does not close the port for the admission of steam until it is in its central position on the seat and, as with the eccentric only a quarter of a revolution ahead of the main pin, it is not in this position until the main pin is on the center, whatever the travel of the valve, steam will be admitted to the cylinders throughout the full stroke of the piston, and the engine will use as much steam working against a light as against a heavy load. In order to govern the period for the admission of steam, or, in other words, give a variable cut-off, the valve must be redesigned so that it will close the steam port before it reaches its central position; that is, it must be given 'lap,' the lap of a valve

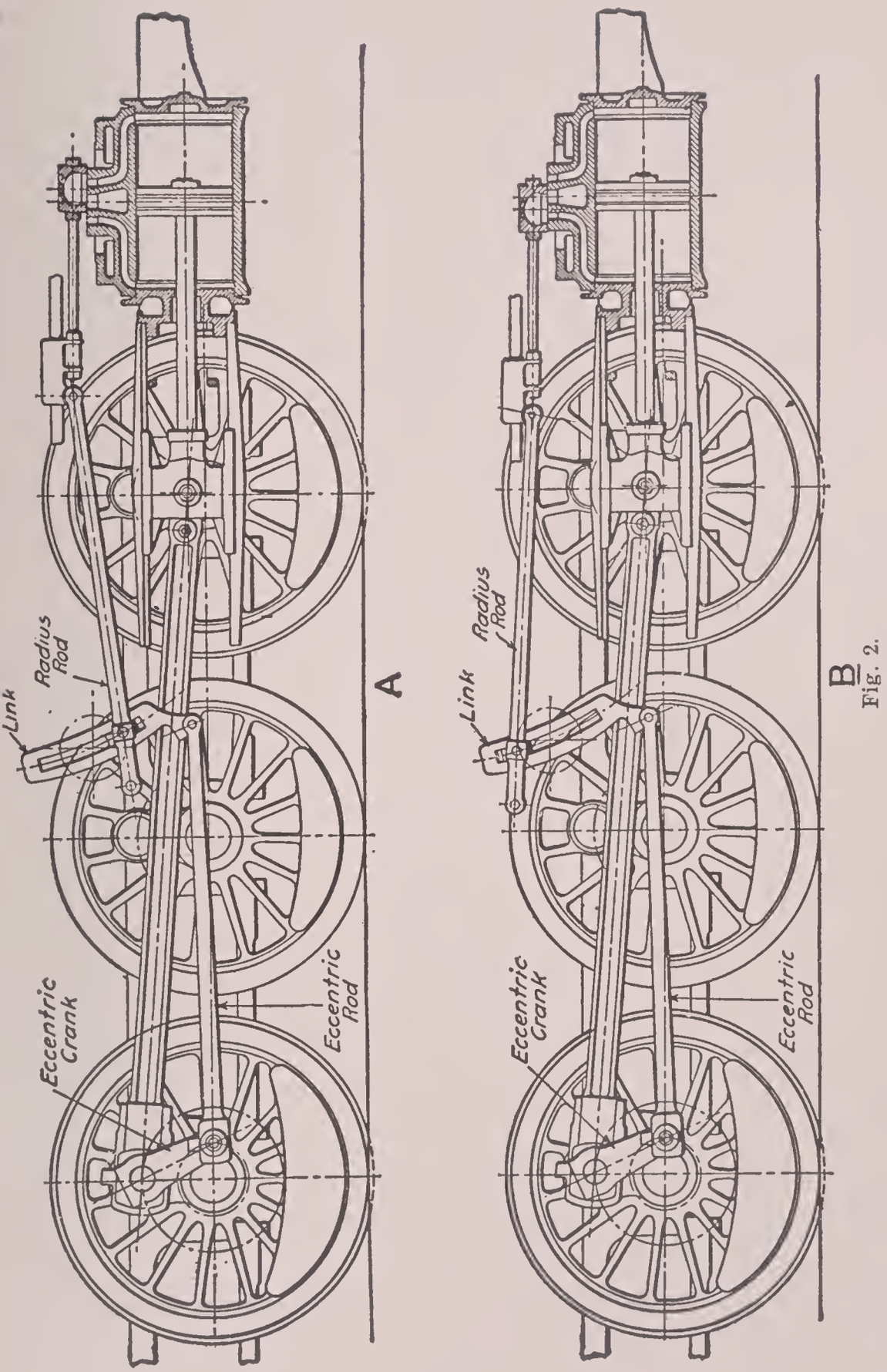

Radius Rod
Link
Eccentric Crank
Eccentric Rod
A
Radius Rod
Link
Eccentric Crank
Eccentric Rod
B

Fig. 2.

being that portion of it which overlaps the steam ports when it is on its central position on the seat. But with lap given to the valve and also 'lead,' which is the width of the opening of the steam port given by the valve when the piston is at the beginning of its stroke, the valve motion must be so changed that the valve will be advanced from its central position on the seat a distance equal to the amount of the lap plus the lead, when the crank pin is on either of the centers.

"It is apparent, from an examination of Fig. 3, that this advance of the valve can not be obtained by any change in the position of the eccentric crank relative to the main pin. Fig. 3 shows the same valve motion as was shown in Fig. 2, except that the valve has one inch outside lap and the eccentric crank has been advanced to more than a quarter of a revolution ahead of the main pin. If then the link block is at the bottom of the link, as in position 'A,' the advance given to the eccentric will have moved the valve forward a distance equal to the lap plus the lead, and the back port will be opened for the admission of steam and the engine will run forward. If, on the other hand, the link block is moved to the upper end of the link, as shown in position 'B,' the advance given to the eccentric crank will have had the opposite effect and the front port will be opened and the reversibility of the engine thus destroyed. In order to provide lead, therefore, in any engine where there is but one eccentric, some means must be employed other than advancing or receding the position of that eccentric relative to the main pin, if there is to be any method of reversing the engine.

"In the Walschaert valve gear the motion for provid-

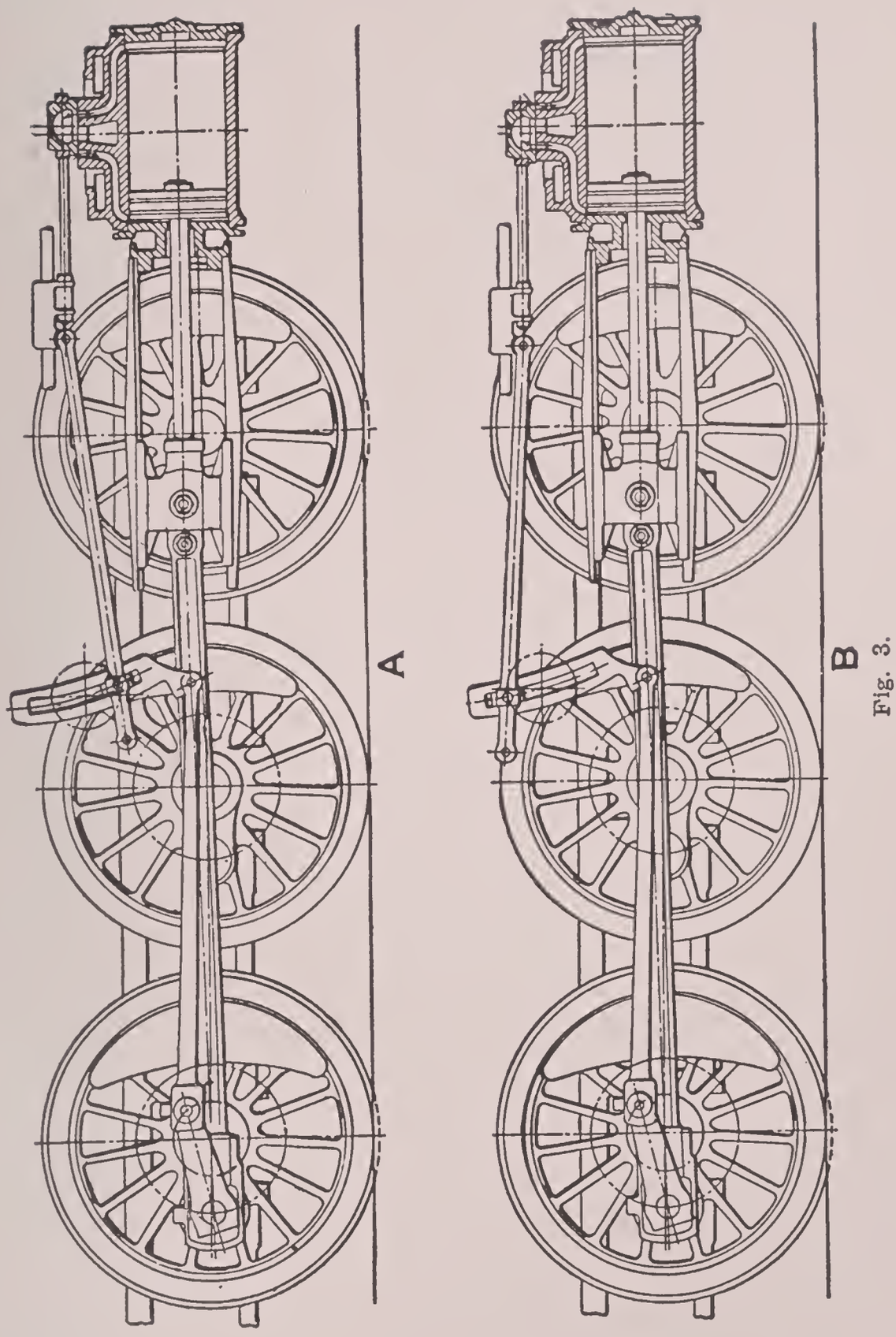


Fig. 3.

ing lap and lead to the valve is derived from the main pin by suitable connections with the crosshead.

"This brings us to the next step in the development of the Walschaert valve gear and the introduction of the lap and lead lever. Suppose that our link block is in the center of the link as shown in position 'A,' Fig. 4. As the center of the link block coincides with the center of the link support, there will be no movement of the radius rod as the link swings back and forth through the action of the eccentric. If then the radius rod was connected with the lap and lead lever at the point 'R,' and the upper end of the lever was connected to the valve stem crosshead at 'V,' and the lower end to the crosshead arm by means of a short link, as shown, as this latter moves back and forth, the point 'R' being fixed, the point 'V' will rotate about it and the valve will be moved back and forth. With the main pin on the forward center, as shown in position 'A,' the angle assumed by the lap and lead lever has moved the valve back a sufficient distance to uncover the front port. With the main pin on the back center, as shown in position 'B,' the lap and lead lever is inclined in the opposite direction and the valve moved forward, and the back port is open. This is the way the Walschaert valve gear derives its lead. The distances between the connecting points of the lap and lead lever must be so proportioned that the travel of the crosshead from one end of the stroke to the other will give a travel to the valve equal to twice the lap plus the lead. That this lead is permanent and does not vary as the reverse lever is hooked up will be shown later on.

"The position of the eccentric crank relative to the main pin depends on which end of the link is used for

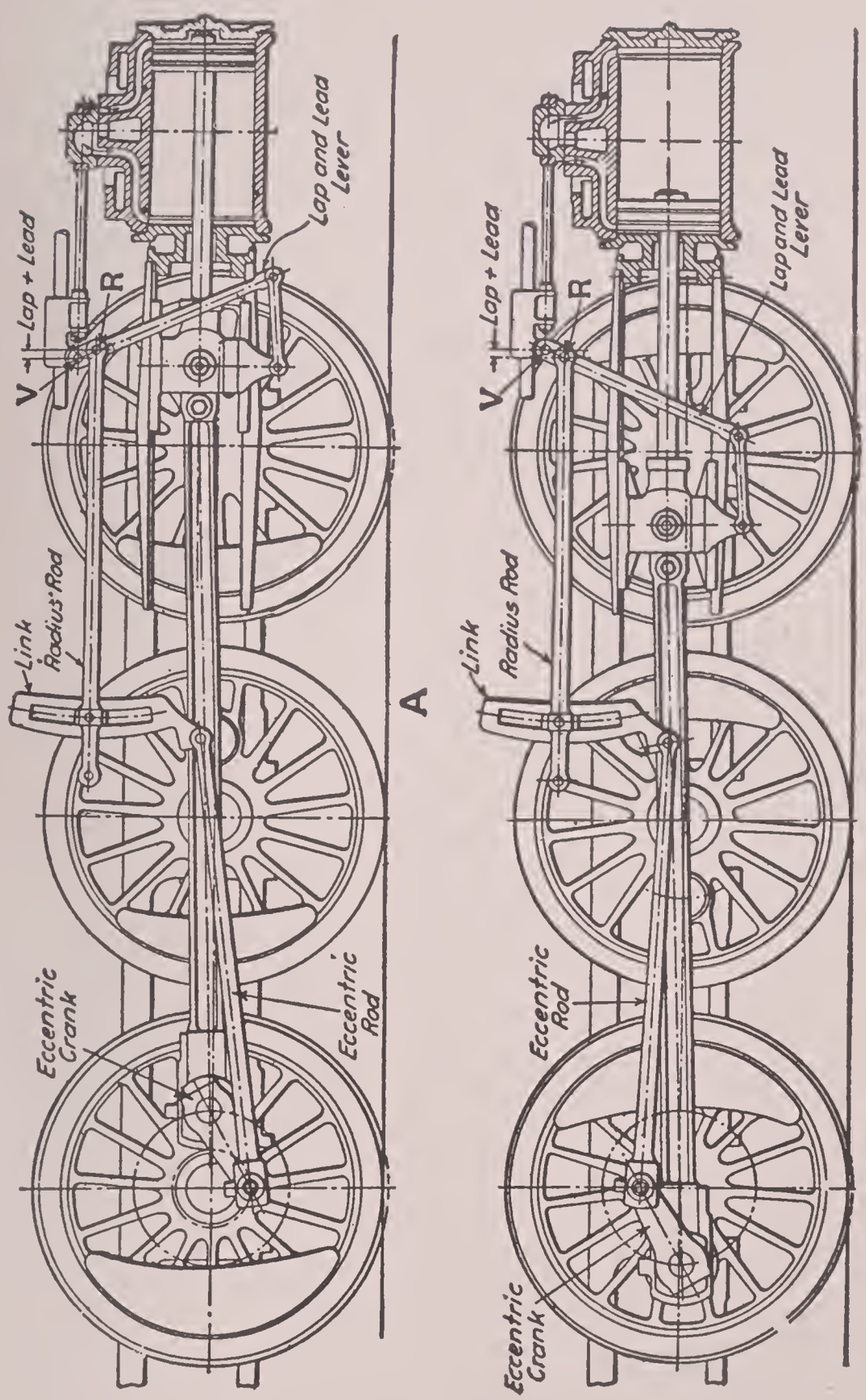

Lap and Lead Lever
Lap + Lead
V
R
Link
Radius Rod
Eccentric Crank
Eccentric Rod
A
Lap and Lead Lever
Lap + Lead
V
R
Link
Radius Rod
Eccentric Rod
Eccentric Crank
B

Fig. 4.

forward motion. If the forward motion is taken from the bottom of the link, as is usually the case, the eccentric crank is a quarter of a revolution ahead of the main pin when the wheel is running forward, if the valves have outside admission; and a quarter of a revolution behind it, if the valves have inside admission. If the top of the link is used for forward motion, the eccentric crank is a quarter of a revolution behind the main pin, if the valves have outside admission; and a quarter of a revolution ahead of it, if the valves have inside admission. In all cases, if the valves have outside admission, the radius rod is connected to the lap and lead lever below the valve stem, and above it, if the valves have inside admission.

"The simple form of direct valve motion, shown in the first figure, has now been so modified that the engine is reversible and has a variable cut-off. It only remains to provide the necessary reversing mechanism and we have the Walschaert valve gear in its complete form as shown in Fig. 5, which represents its application to a consolidation engine.

"Figure 6 shows a general outline of the gear as arranged for inside admission valves on which are given the names of the various parts as recommended by the American Railway Master Mechanics' Association. Starting at the crank pin, we have the eccentric crank, eccentric rod, link, reach rod, lift shaft, radius rod hanger, radius rod, lap and lead lever, lap and lead lever connector, and crosshead arm.

"Having studied the functions of the different parts of the Walschaert valve gear, it remains to trace the movement of the valve through a complete revolution of

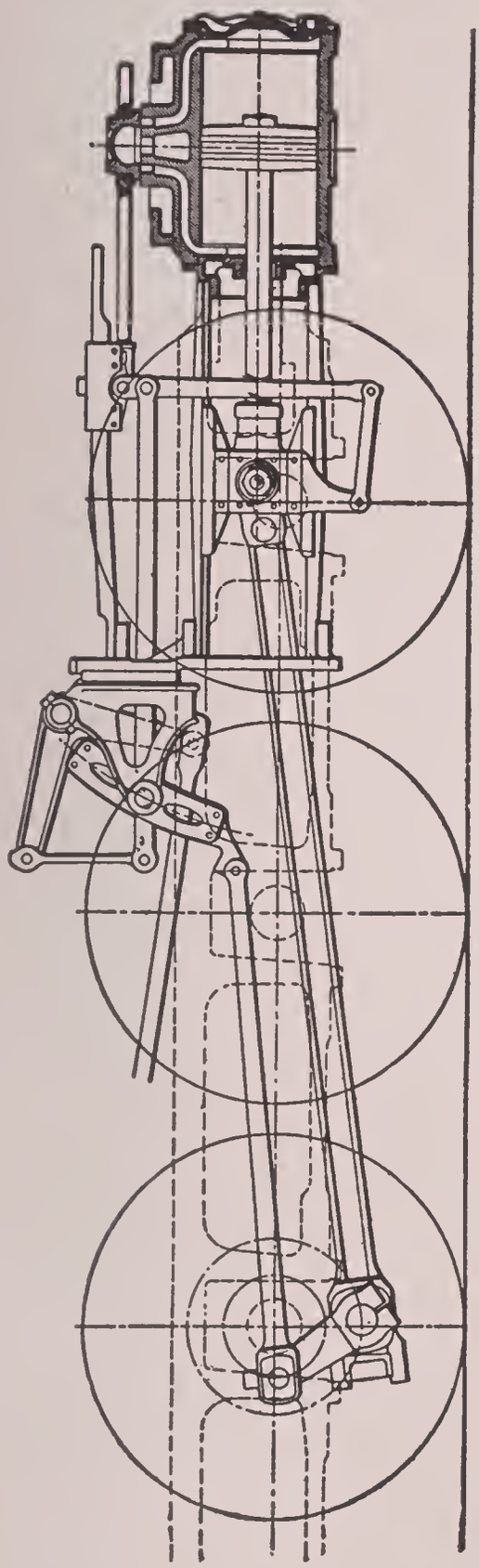


Fig. 5.

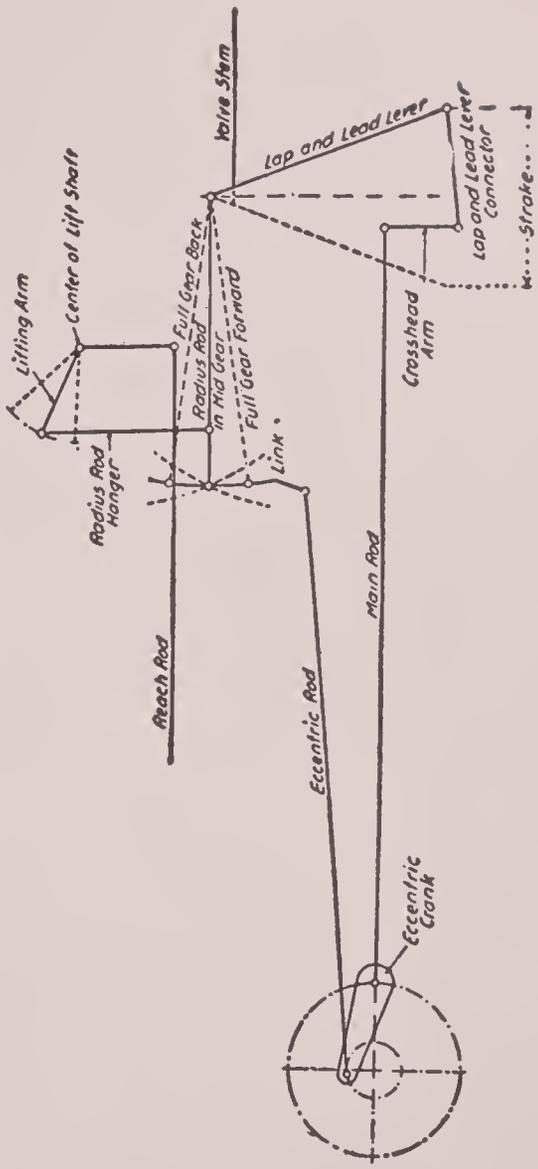

Valve Stem
Lap and Lead Lever
Lap and Lead Lever Connector
Stroke
Center of Lift Shaft
Lifting Arm
Full Gear Back
Radius Rod
In Mid Gear
Full Gear Forward
Crosshead Arm
Link
Radius Rod Hanger
Main Rod
Reach Rod
Eccentric Rod
Eccentric Crank

Fig. 6.

the wheel. Figs. 7, 8, 9 and 10 show a series of diagrams representing different positions of the valve for different positions of the crank pin. For the sake of simplicity, the valve and cylinder are shown in section, while the other parts of the gear are represented by their center lines and center points only. As will be apparent, these diagrams are out of proportion, the valve and the eccentric throw having been enlarged in order to bring out more clearly the positions of the edges of the valve relative to the edges of the cylinder ports. In Fig. 7, the valve is outside admission and the motion is represented as being in full forward gear; or with the reverse lever in the extreme forward position. Fig. 8 represents the same valve motion, but in this case the reverse lever is hooked up and the link block is nearer the center of the link and the engine is cutting off at about 25 per cent of the stroke. Figs. 9 and 10 represent a valve motion as arranged for an inside admission piston valve; in Fig. 9 the motion being in full gear forward; while in Fig. 10 it is represented with the reverse lever hooked up.

"As has already been shown, the valve receives its motion from two distinct sources; first, from the eccentric crank, which gives the long travel to the valve; and second, from the crosshead by means of the lap and lead lever, which would give a short travel to the valve even if the eccentric rod was disconnected.

"Starting with diagram 1, Fig. 7, as the valve is outside admission, with the main pin on the back center, the eccentric crank is on the top quarter, or a quarter of a revolution ahead of the pin, and the radius rod is connected to the lap and lead lever below the valve stem.

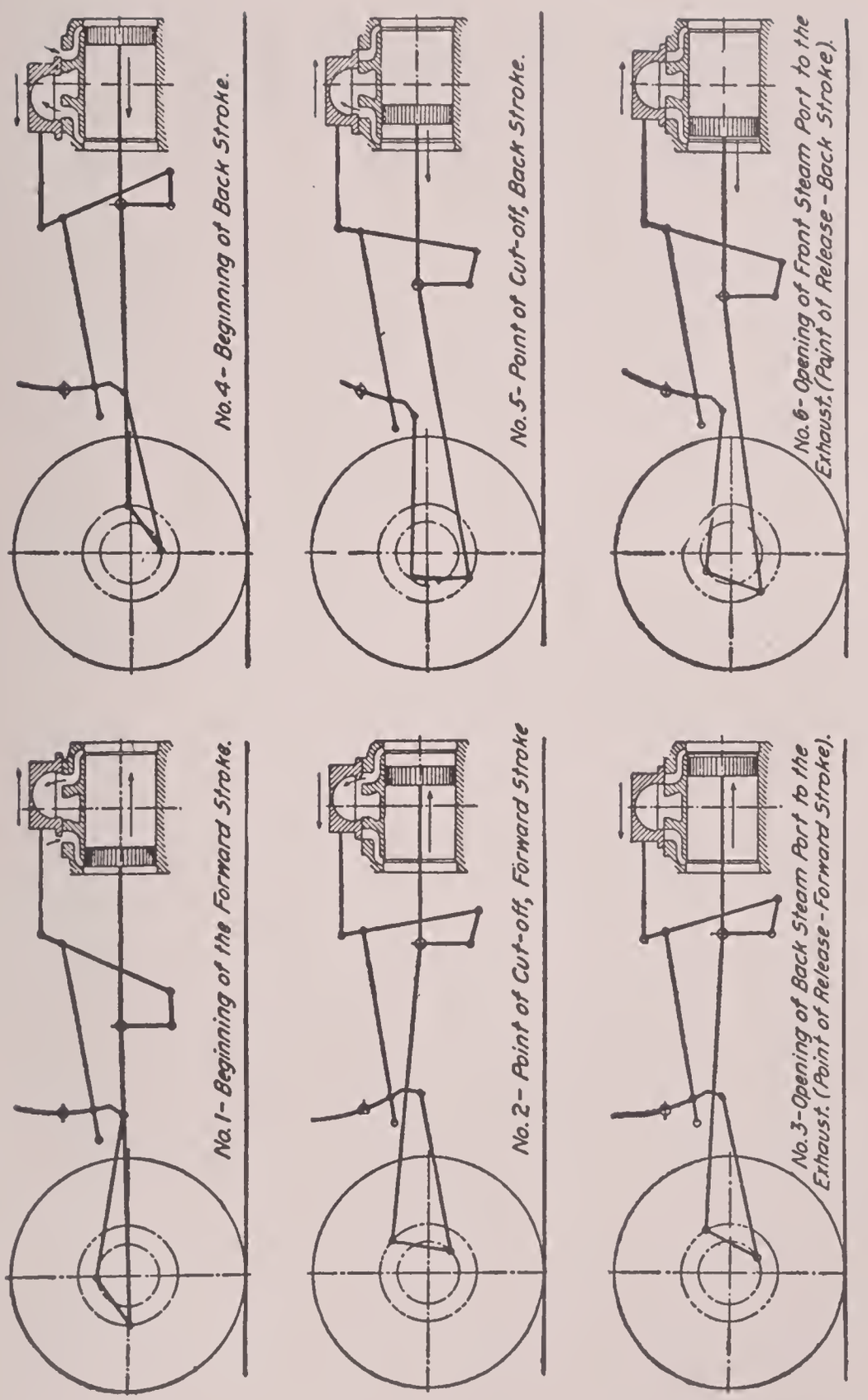

No. 1- Beginning of the Forward Stroke.
No. 2- Point of Cut-off, Forward Stroke
No. 3- Opening of Back Steam Port to the Exhaust. (Point of Release - Forward Stroke).
No. 4- Beginning of Back Stroke.
No. 5- Point of Cut-off, Back Stroke.
No. 6- Opening of Front Steam Port to the Exhaust. (Point of Release - Back Stroke).

Fig. 7.

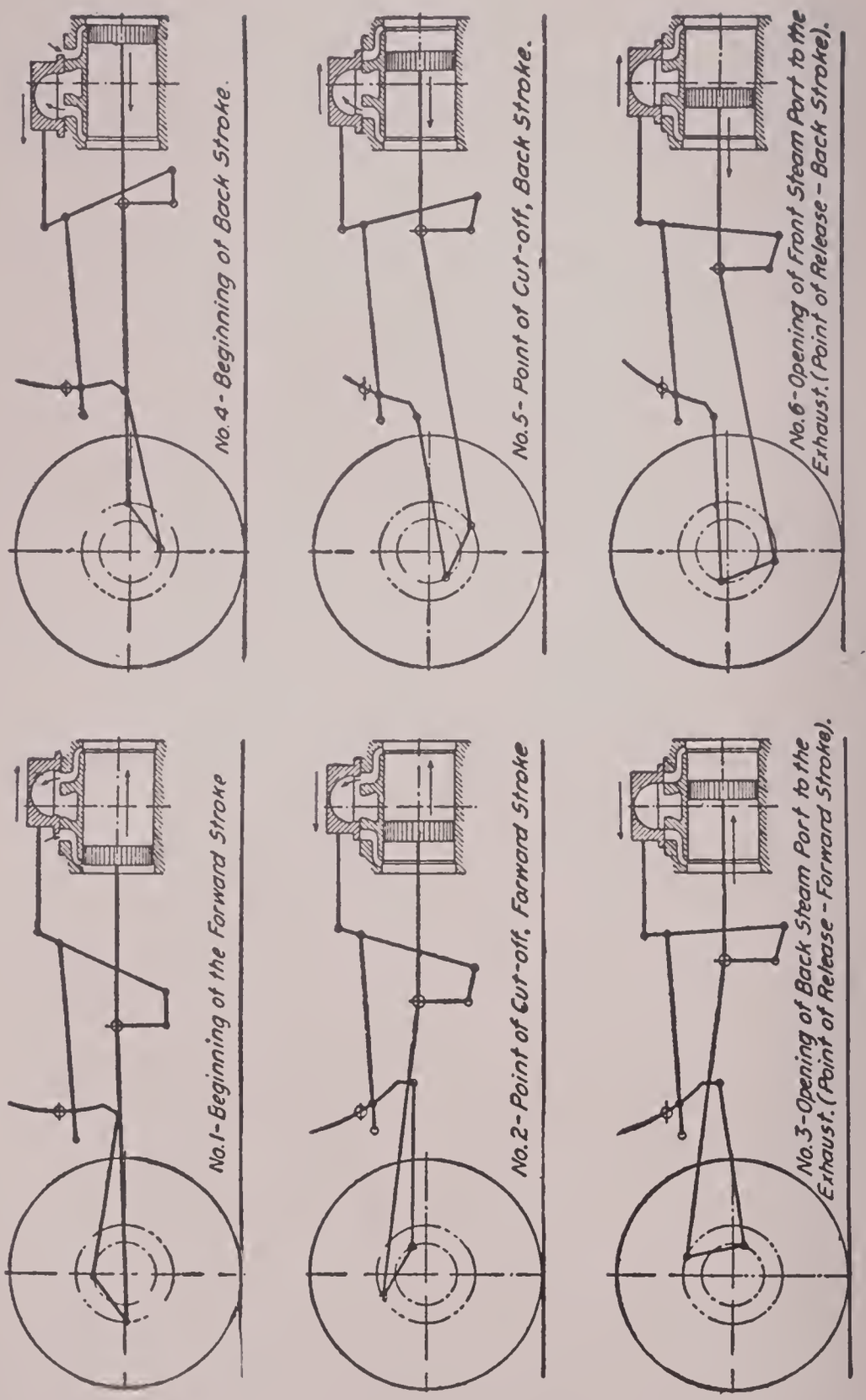

No. 4 - Beginning of Back Stroke.
No. 5 - Point of Cut-off, Back Stroke.
No. 6 - Opening of Front Steam Port to the Exhaust. (Point of Release - Back Stroke).
No. 1 - Beginning of the Forward Stroke
No. 2 - Point of Cut-off, Forward Stroke
No. 3 - Opening of Back Steam Port to the Exhaust. (Point of Release - Forward Stroke).

Fig. 8.

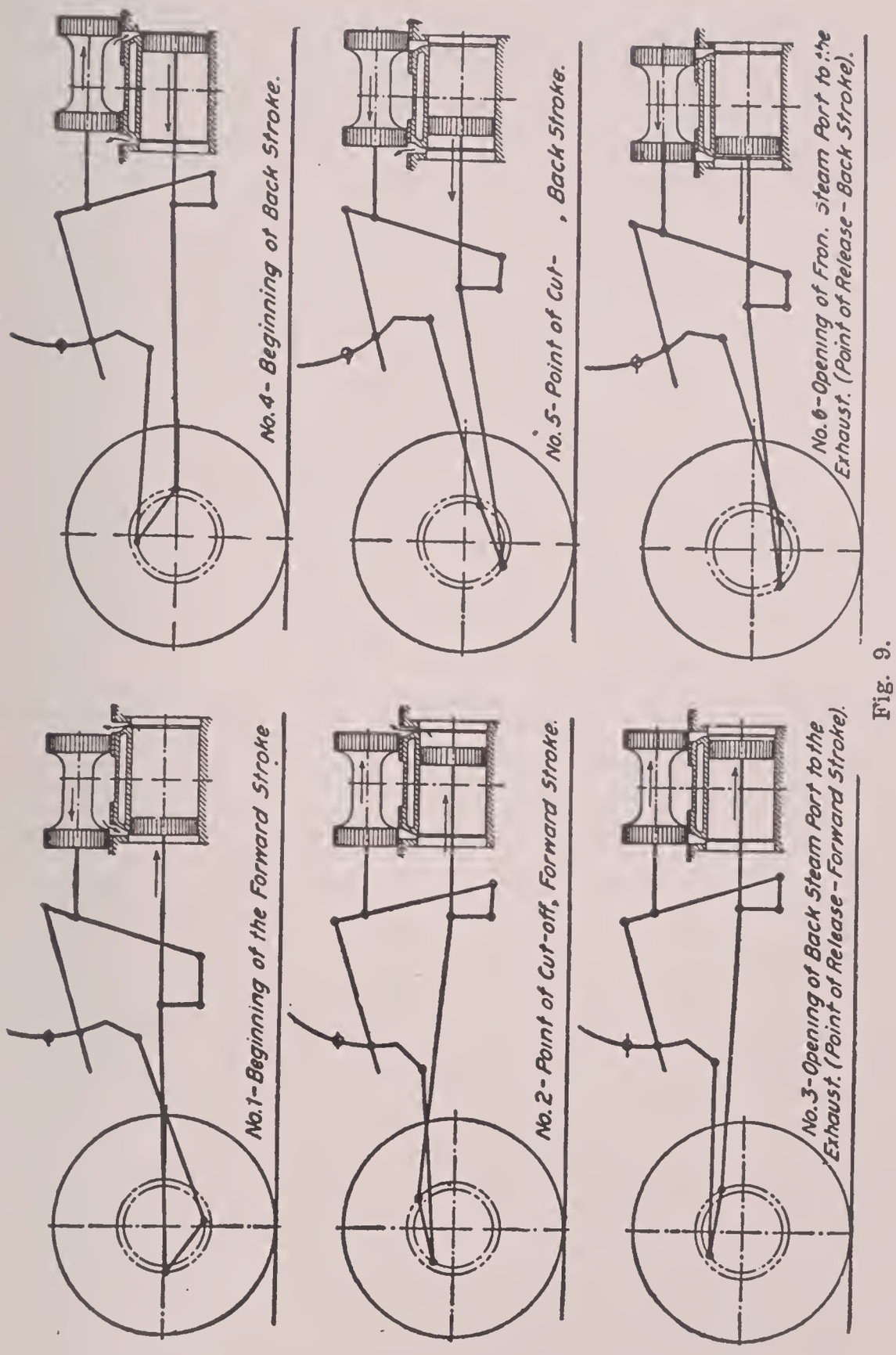

No. 1 - Beginning of the Forward Stroke.
No. 2 - Point of Cut-off, Forward Stroke.
No. 3 - Opening of Back Steam Port to the Exhaust. (Point of Release - Forward Stroke).
No. 4 - Beginning of Back Stroke.
No. 5 - Point of Cut- , Back Stroke.
No. 6 - Opening of Fron. Steam Port to the Exhaust. (Point of Release - Back Stroke).

Fig. 9.

The link is in its central position, and the valve would be in its central position on the seat, if it were not for the motion given to it by the lap and lead lever. As it is, however, the crosshead being at the back end of the stroke, the lower end of the lap and lead lever is at its extreme back position and the angle assumed by the lever has moved the valve forward, as indicated by the arrow, a distance equal to the lap of the valve plus the lead. Going to diagram 1, in Fig. 8, the main pin, eccentric crank and crosshead are in the same position as they were in the corresponding diagram in Fig. 7; and the link is in its central position. Thus, although the link block is nearer the center of the link, the radius of the link being equal to the length of the radius rod, the front end of the radius rod is the same horizontal distance from the center of the crosshead as it is in diagram 1, Fig. 7; consequently the angle assumed by the lap and lead lever is the same and the valve has been moved forward the same distance from its central position, and the lead is the same as it is with the reverse lever in full gear.

"In Figs. 9 and 10, diagram 1 in each case represents the position of the valve at the beginning of the forward stroke; the same as the corresponding diagrams in Figs. 7 and 8. As the valves are inside admission, however, the radius rod is connected to the lap and lead lever above the valve stem. The valve, in each case, has thus been moved back, instead of forward, by the movement of the lap and lead lever; and the back port is open to the live steam and the front port to the exhaust.

"Going back to Fig. 7; in diagram 2, the piston has moved forward a distance equal to about 85 per cent of the stroke; the valve has traveled to its extreme for-

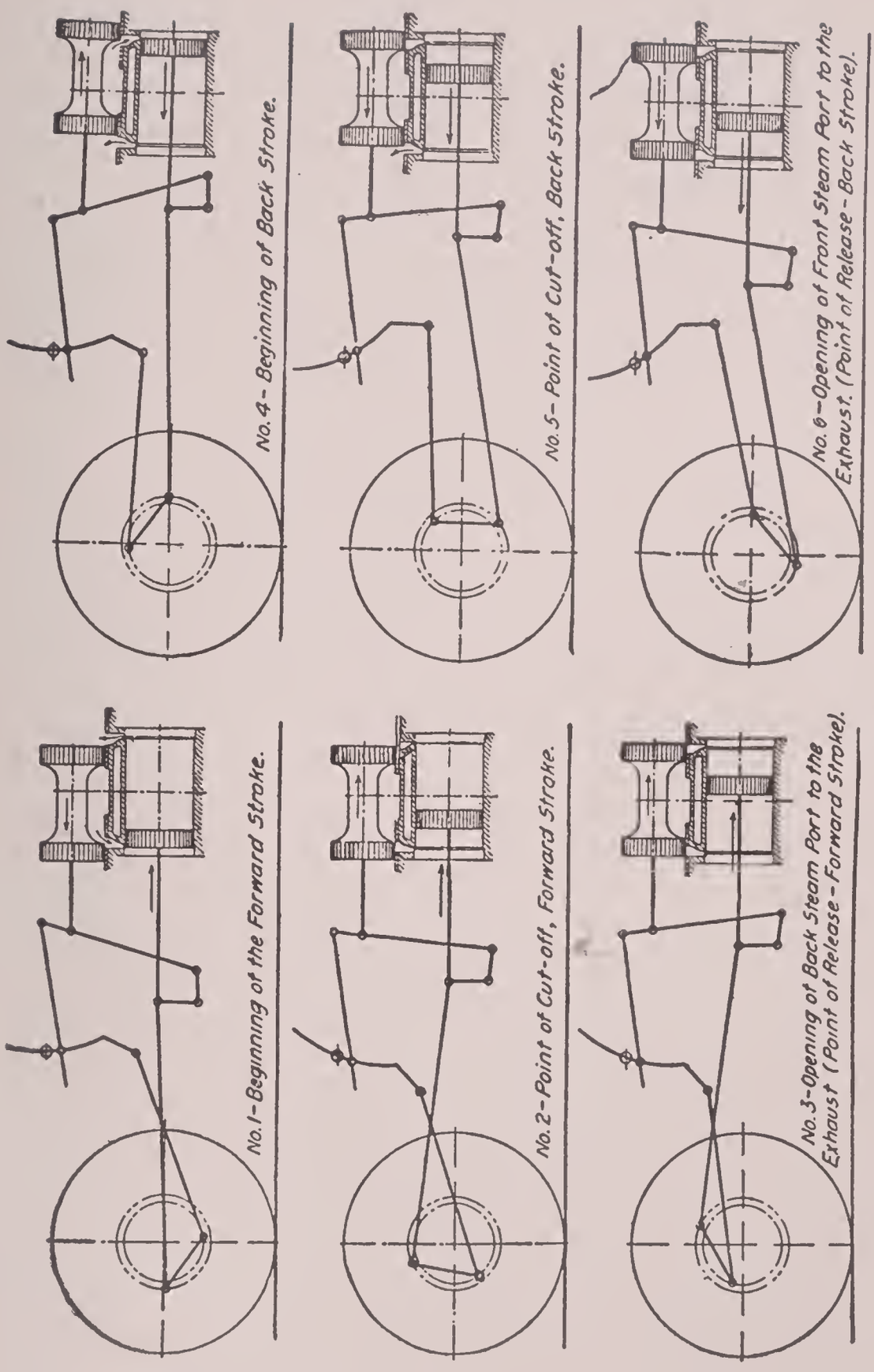

No. 1 - Beginning of the Forward Stroke.
No. 2 - Point of Cut-off, Forward Stroke.
No. 3 - Opening of Back Steam Port to the Exhaust (Point of Release - Forward Stroke).
No. 4 - Beginning of Back Stroke.
No. 5 - Point of Cut-off, Back Stroke.
No. 6 - Opening of Front Steam Port to the Exhaust. (Point of Release - Back Stroke).

Fig. 10.

ward position and back again, as indicated by the arrow, till it has just closed the back steam port; while the front port is still open to the exhaust. In other words, the valve is at the point of cut-off. In diagram 3, the piston has moved still nearer to the forward end of the stroke. The exhaust edge of the valve is now in line with the edge of the back steam port; so that any further movement will open communication with this port and the exhaust. The front port, on the other hand, has been closed to the exhaust and whatever steam is ahead of the piston will be compressed. In diagram 4, the piston is at the extreme forward end of the stroke; the angle assumed by the lap and lead lever has moved the valve back a distance equal to the lap plus the lead; the front port is open for the admission of steam and the back port is open to the exhaust. In diagram 5, the piston is moving toward the back end of the cylinder and the valve has just closed the front port to the admission of steam, showing the cut-off position of the valve on the back stroke. In diagram 6, the piston is very nearly at the end of the back stroke and the valve is about to open the front port to the exhaust, while the back port is closed to the exhaust and compression is taking place in the back end of the cylinder.

"As the diagrams in Figs. 8, 9 and 10 represent the same valve events as the corresponding diagrams in Fig. 7, it will not be necessary to examine them separately. It will be noticed that in Figs. 8 and 10 the valve cuts off the steam from the cylinders and opens the steam ports to the exhaust at a much earlier period in both the forward and back stroke than it does in Figs. 7 and 9, which shows the effect of hooking up the reverse lever.

"These diagrams show very plainly the difference in

the arrangement of the Walschaert valve gear for outside and inside admission valves, also the fact that the lead of the valve is the same for all cut-offs.

"To change the lead of the Walschaert valve gear, it is necessary to either change the lap of the valve, reducing it to increase the lead and increasing it to reduce the lead, in which case the cut-offs will occur at later or earlier periods in the stroke, respectively, or to change

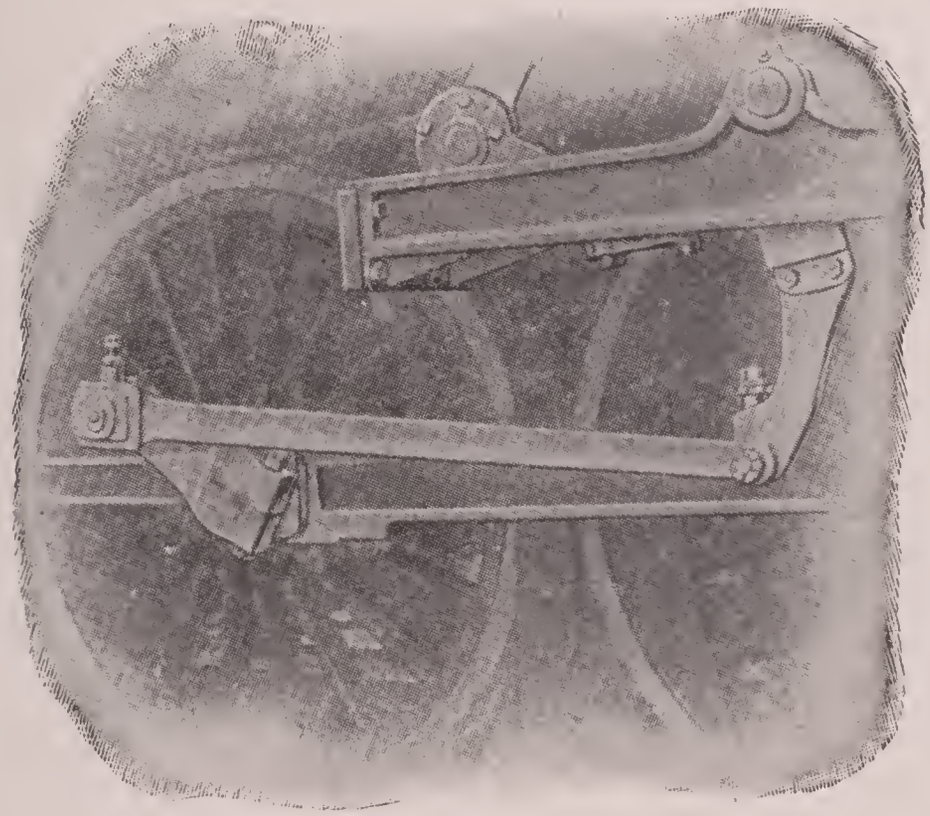


Fig. 11.

the lengths of the arms or distances between the connecting points of the lap and lead lever. Increasing the distance between the radius rod connection and the valve stem connection to the lap and lead lever would increase the lead; or shortening this distance would decrease the lead.

"Just here it might be of interest to study some of the

ordinary forms of construction of the various parts of the gear.

"In Fig. 11 are shown an eccentric crank and eccentric rod. The eccentric crank, as will be seen, is secured to the extension of the main crank pin by a binding bolt. The crank is split so that it can be drawn to a tight bearing by means of the bolt. This bolt, together with a key, keeps the eccentric crank fixed in its position on the

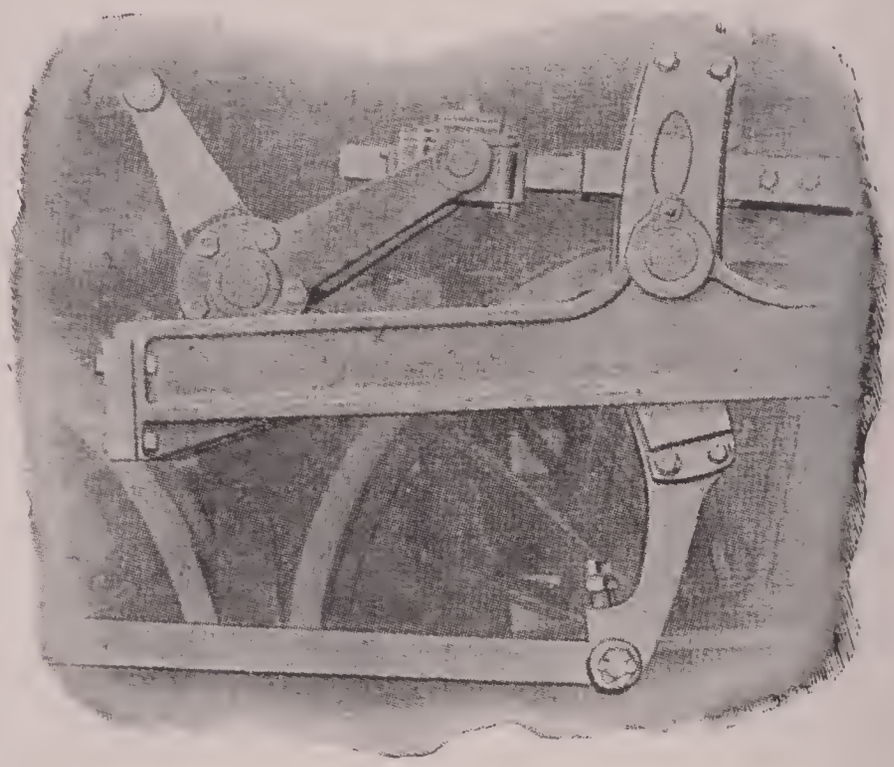


Fig. 12.

main pin. By driving out the binding bolt, the eccentric crank may be taken off if necessary. This construction permits of using a solid bushing on the side rod at the main crank pin.

"The link and reverse shaft are shown in Fig. 12. In this design of gear, the radius rod is directly connected to the lift shaft arm by means of a slip block, which makes a very simple arrangement.

"Fig. 13 shows another style of reversing mechanism. In this design, the backward extending arm of the lift shaft is connected to the back end of the radius rod by means of a link.

"In Fig. 14 are shown the parts of the Walschaert valve gear connecting the valve stem and the crosshead. It will be noticed that the radius rod connection with the lap and lead lever is above the valve stem connection, showing that the valve is inside admission.

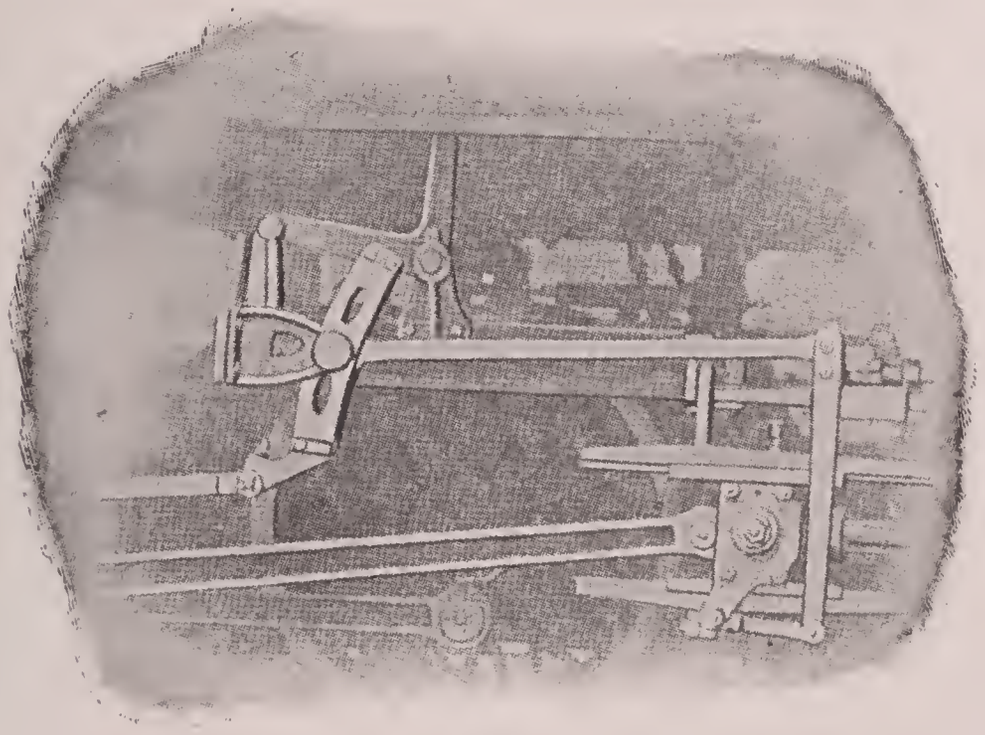


Fig. 13.

"Having considered the principles of the Walschaert valve motion, the next phase of the subject to take up, and that which is of most interest to all engineers, is—what may be done in case of a break-down. It would be impossible to lay down rules to cover every case that might arise; but we can take up some of the more usual or most possible failures and consider the best and quickest course to follow in such cases.

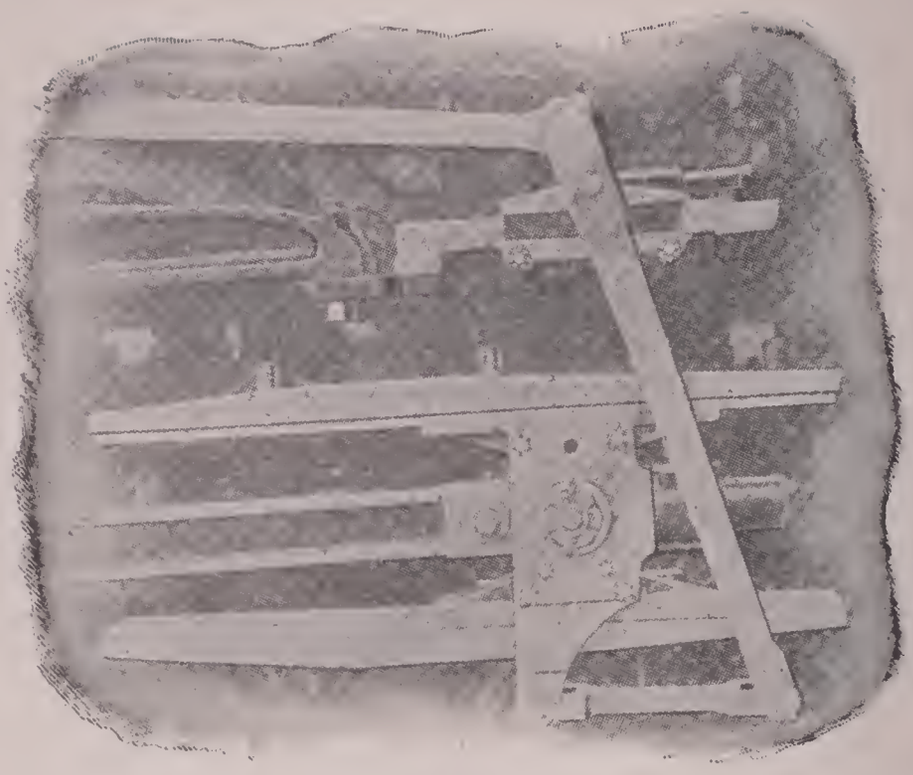


Fig. 14

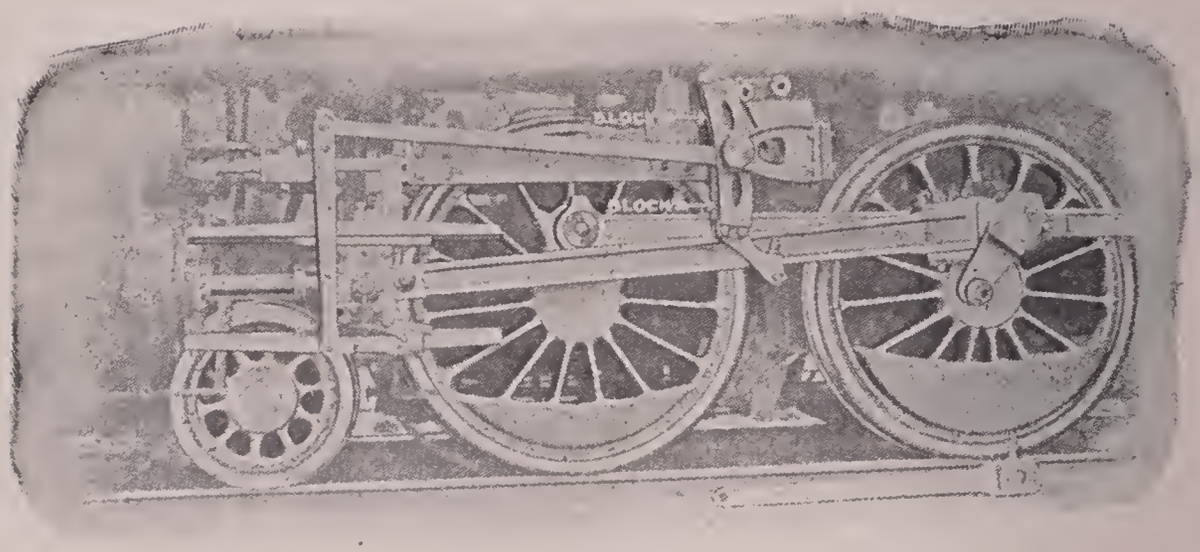


Fig. 15.

"Suppose, for instance, an eccentric crank, eccentric rod, or the foot of the link is broken; or one of the link trunnions twisted off, the other trunnion holding the link in position. In such cases, take down the eccentric rod, disconnect the back end of the radius rod from the

lift shaft arm and secure the link block in the center of the link. With the motion disconnected and blocked in this way, the valve on the lame side receives a travel from the lap and lead lever equal to twice the amount of the lap plus the lead, which gives a port opening equal to the amount of the lead. This permits of leaving the main rod up and running in with both sides; as the cylinders can be lubricated and, though the cut-off will be very short on the disabled side, the steam that is admitted will do a certain amount of work and the engine can be reversed.

"Fig. 15 shows an engine with the valve gear disconnected and blocked as just described. In the design illustrated, the radius rod is connected to the lift shaft arm by means of a radius rod hanger so that it can be readily disconnected by taking out the pin connecting the radius rod hanger and the lift shaft arm. The link block is secured in the center of the link by means of the two blocks shown, one placed below and the other above the link block and securely wedged in position.

"With the link block secured in the center of the link, care must be taken in making a stop that the main pin on the lame side is not on either quarter; as, in this case, the lap and lead lever would be in a perpendicular position, as shown in the illustration, and the valve would be central on the seat; and, as the pin on the other side would be on the dead center, it would be impossible to move the engine.

"In some arrangements of the Walschaert valve gear, the radius rod is directly connected to the lift shaft arm by means of a slip block or crosshead. It is common practice in such cases to make the lift shaft arm in two pieces so that the radius rod may be easily disconnected

from it, as shown in Fig. 16. Remove the outer section of the lift shaft arm, take off the cap of the slip block, lift out the end of the radius rod and remove the slip block. The parts that it is necessary to take down are shown in the foreground. The link block is secured in the center of the link in the same way as in the previous case.

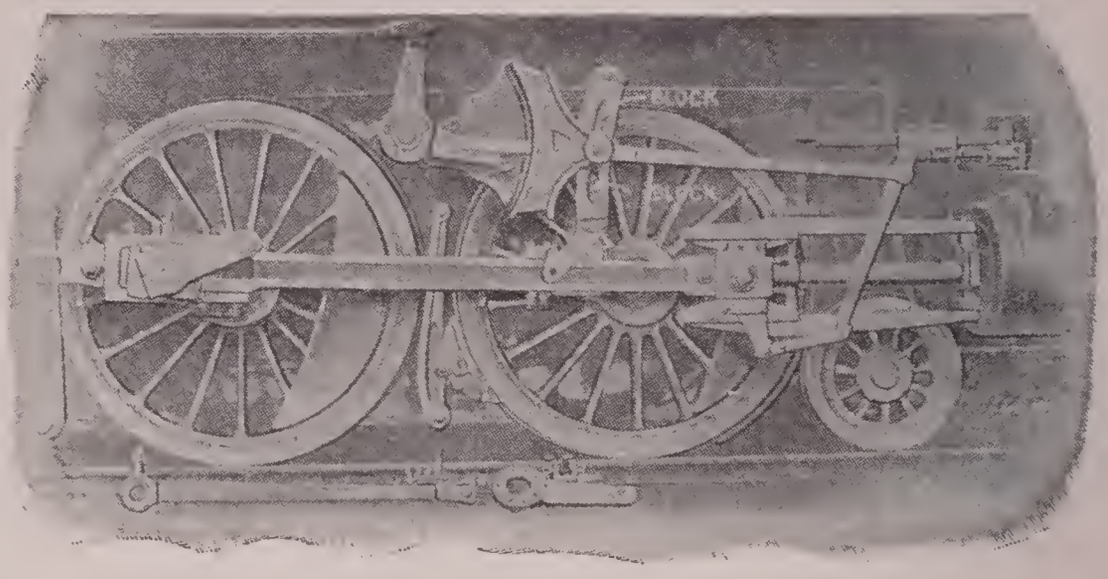


Fig. 16.

"So far, we have not considered any accidents which would require blocking the valve to cover the ports. In all cases where this is necessary, if the engine has no relief valves in the cylinder heads to remove, it is good practice to take down the main rod on the disabled side.

"Suppose, for instance, the main rod was broken, or the piston rod bent, or a cylinder head knocked out. In any of these cases, if the valve has inside admission and there are no relief valves in the cylinder heads, the engine may be disconnected and blocked, as shown in Fig. 17. Disconnect the front of the radius rod from the lap and lead lever and suspend it clear of the latter by means of a wire or chain from some convenient support.

Secure the valve to cover the ports. This can usually be done by means of the set screw provided in the valve stem crosshead for this purpose; but, if there is no such set screw, the valve stem crosshead may be blocked. Take down the main rod and block the crosshead at the back end of the guides, as shown. With the valve motion disconnected in this way, the reverse lever is free to operate the other side and the engine can be run in

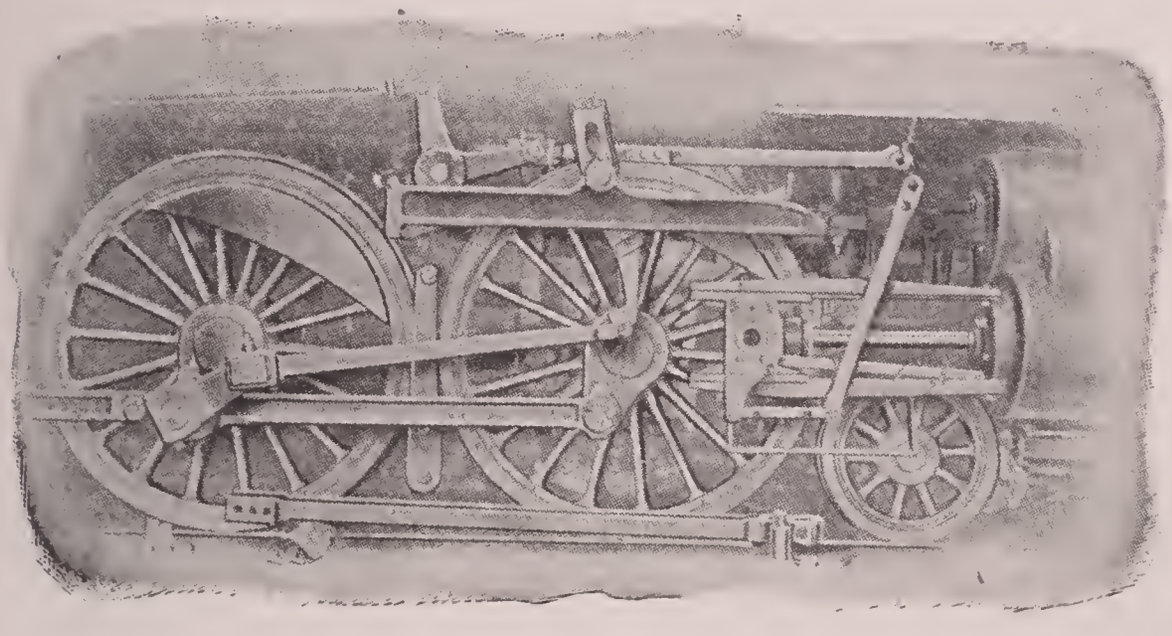


Fig. 17.

on one side. If the crosshead arm, lap and lead lever connector, or lap and lead lever is broken, the engine might be blocked in the same way as illustrated in Fig. 17; except that, of course, such of the broken parts should be removed as would in any way interfere with the running of the engine.

"If the valves have outside admission and there are no relief valves in the cylinder heads, in cases where it is necessary to secure the valve to cover the ports such

as have been considered, the engine might be disconnected as shown in Fig. 18. Disconnect the radius rod from the lap and lead lever and take down the latter, as, otherwise the front end of the radius rod would strike the lever as the radius rod moves back and forth to the motion of the link. Suspend the front end of the radius rod from the valve stem crosshead guide, using for this purpose a wire or chain (the fire door chain if no other is at hand). Secure the valve to cover the ports and take down the main rod and block the crosshead at the back end of the guide.

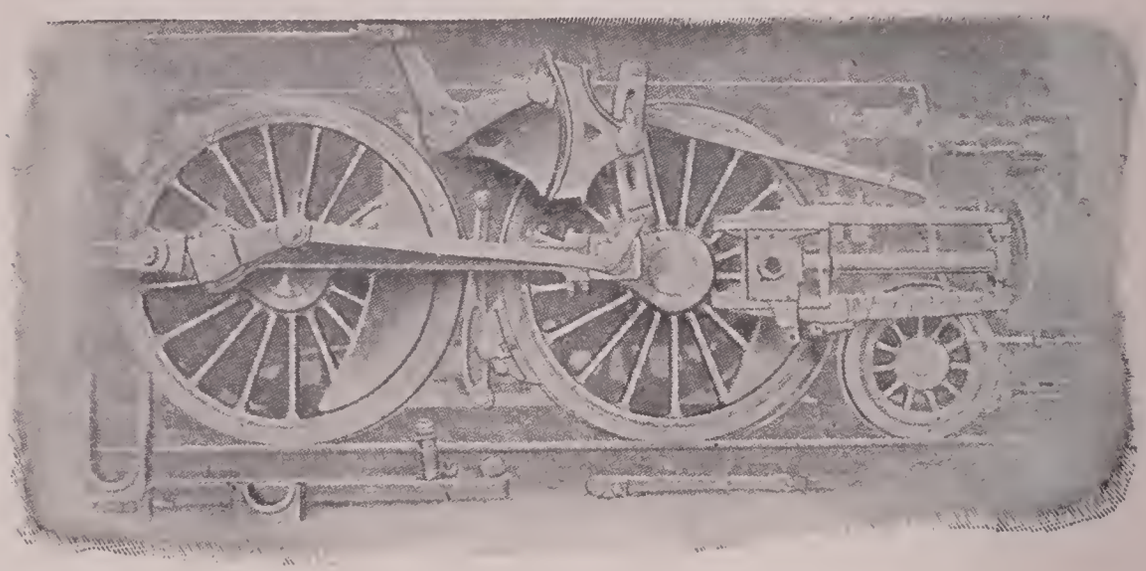


Fig. 18.

"If the engine has cylinder relief valves and the main rod and piston on the disabled side are in condition to run, the main rod may be left up when the valve is secured to cover the ports. In that event, remove the relief valve from the cylinder heads to relieve compression and also permit of lubricating the cylinder.

"Suppose, for instance, the lap and lead lever, lap and lead lever connector, or the crosshead arm were broken;

an engine with inside admission valves and relief valves in the cylinder heads could be blocked, as shown in Fig. 19. Disconnect the radius rod from the lap and lead lever and suspend it clear of the latter, as shown. Secure the valves to cover the ports. Tie the lower end of the lap and lead lever ahead by means of a rope secured to the cylinder cocks. Take out the relief valves, as previously recommended. The engine can then be run in on one side.

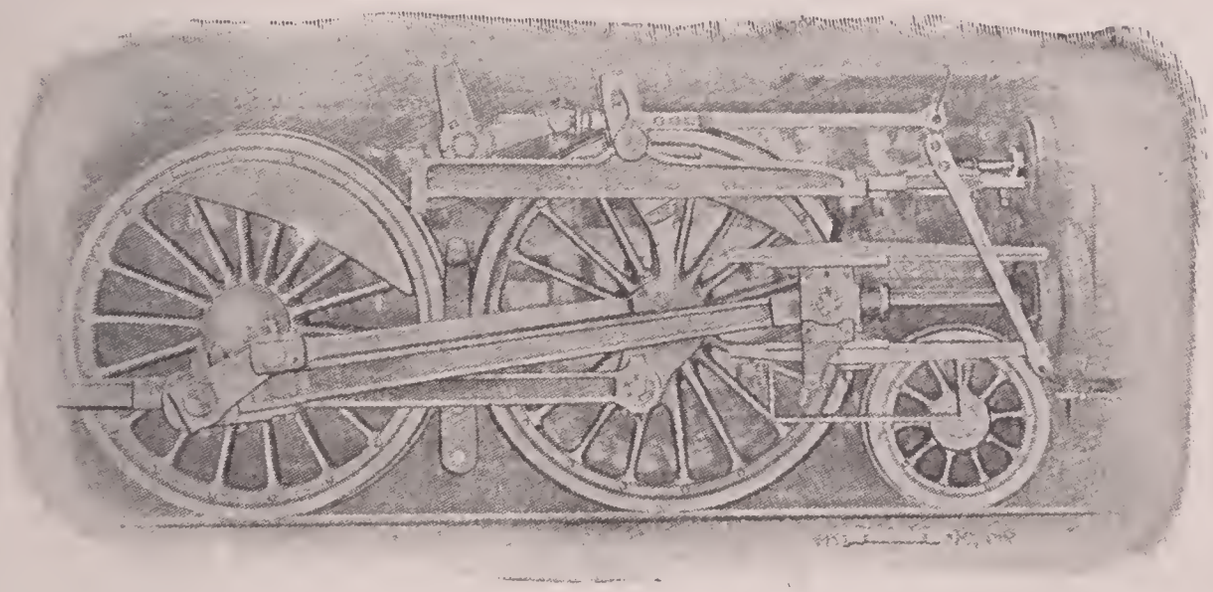


Fig. 19.

"If the valves were outside admission, under the same conditions as assumed in the case illustrated in Fig. 19, the main rod could be left up and the engine disconnected in the same way; except that the lap and lead lever would have to be taken down in order to clear the radius rod.

"We have not attempted to enumerate all the accidents that might occur on the road; but we trust that the explanation of what may be done in the cases considered

will assist the engineer to meet any troubles that might possibly happen to the Walschaert valve motion.

"Although the method of adjusting the Walschaert valve gear is not of as much interest to the engineer as to the 'back shop' or roundhouse man, a few general instructions in regard to setting the valves may not be out of place here.

"1. Ascertain by the following method the position of the eccentric crank: Mark the position of the link on both of the dead centers of the main crank. If the position of the link is the same in both cases the eccentric crank position is correct; if not, the eccentric crank should be shifted until this occurs.

"2. After the eccentric crank has been correctly set, the eccentric rod should be lengthened or shortened, as may be required, to bring the link in its middle position when the main crank is on either of its dead centers, so that the link block may be removed from its extreme forward to its extreme backward position without imparting any motion to the valve. It may be noted that the link position may be observed by the usual tram marks on the valve stem; or directly by marks on the link pin, as may be found most convenient, with the link block in full gear, preferably ahead.

"3. The difference between the two positions of the valve on the forward and back centers of the engine is the lap and lead doubled; it is the same in any position of the link block, and can not be changed without changing the leverage relations of the lap and lead lever.

"4. The tram marks of the opening moments at both ends of the valve should be marked on the valve stem, and the latter lengthened or shortened until equal leads at both ends are obtained.

"5. Within certain limits this lengthening or shortening may be made on the radius bar, if it should prove more convenient; but it is desirable that the length of this bar should be so nearly equal to the radius of the link that no apparent change in the lead should occur in moving the link block, as stated in note No. 2.

"6. The lead may be increased by reducing the lap and the cut-off points will then be slightly advanced. Increasing the lap reduces the opposite effect on the cut-off and reduces the lead the same amount. With good judgment these quantities may be varied to offset the irregularities inherent in transforming rotary into lineal motions.

"It may be of interest, before we end our study of the Walschaert valve gear, to consider some of the different arrangements employed in the application of it to engines of different types and designs.

"Fig. 20 represents the arrangement of the gear as applied to a Pacific type engine built for the New York Central Lines. This engine weighs, in working order, 266,000 pounds, and with one exception—an engine of the same type built for the Pennsylvania—is the heaviest passenger engine ever built. Engines of this design are at present hauling the Twentieth Century Limited, the eighteen hour train between New York and Chicago.

"Fig. 21 shows the arrangement employed in the application of this gear to a Prairie type engine, built for the Northern Pacific Railway.

"Fig. 22 shows the arrangement employed in the application of the Walschaert valve gear to a deGlehn 4-cylinder, balanced compound Pacific type engine for the Paris-Orleans Railway.

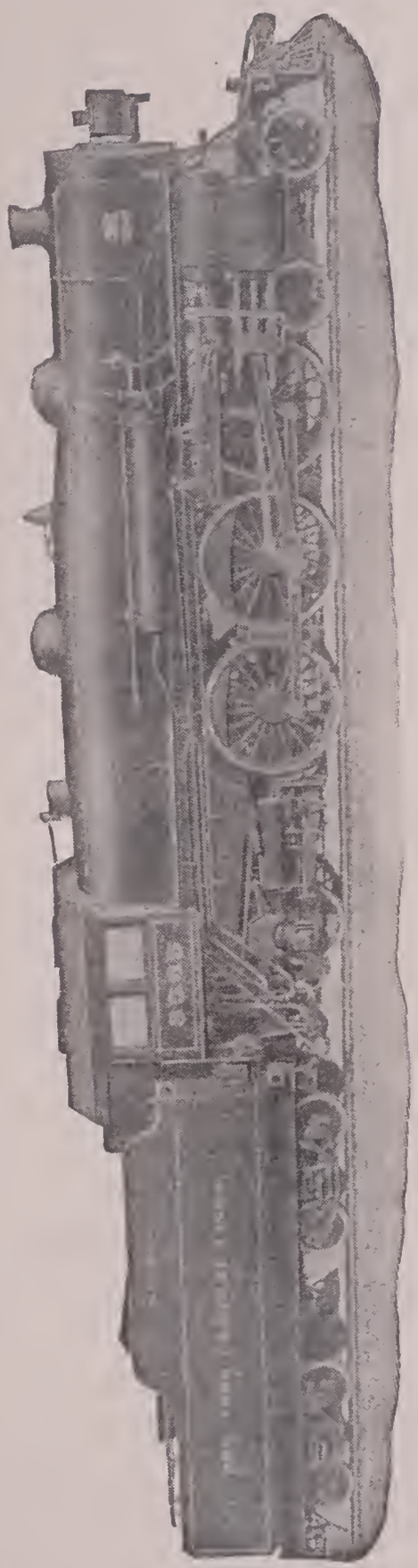


Fig. 20.

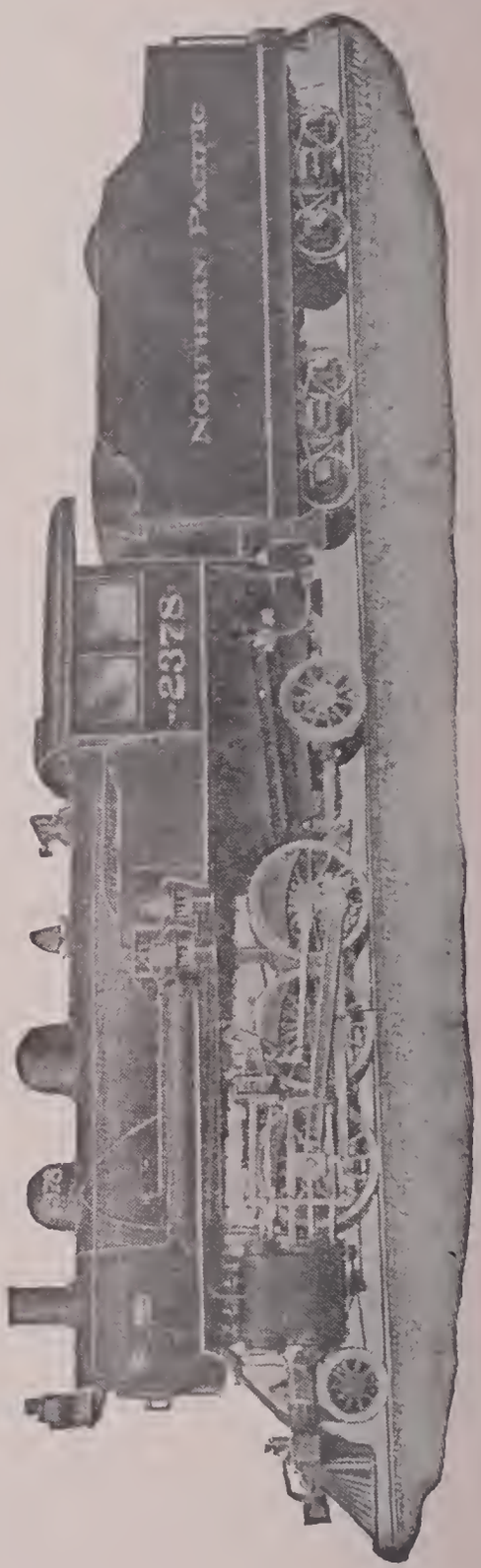


Fig. 21.

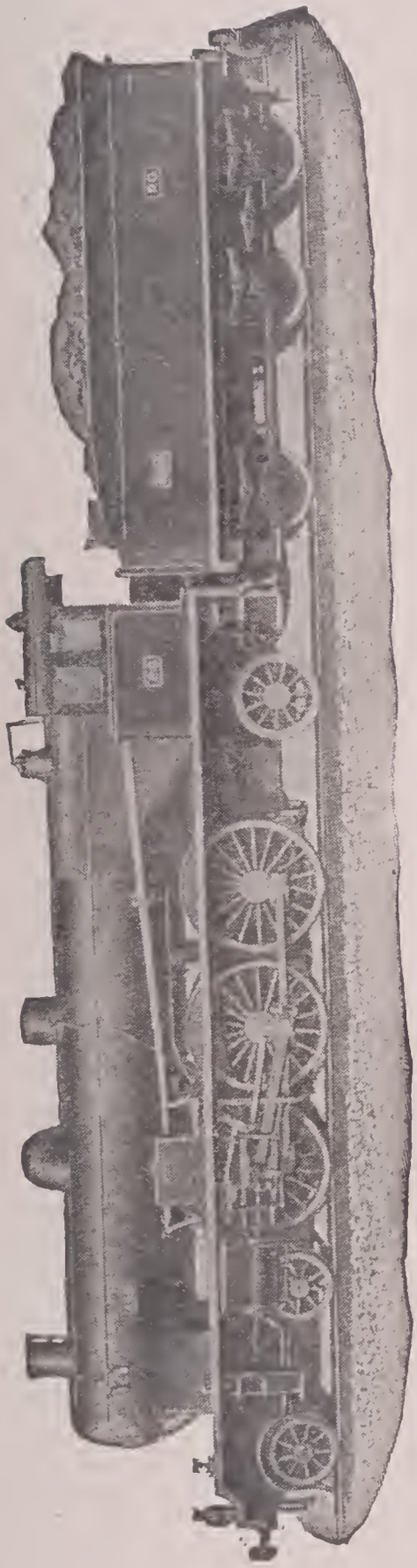


Fig. 22.

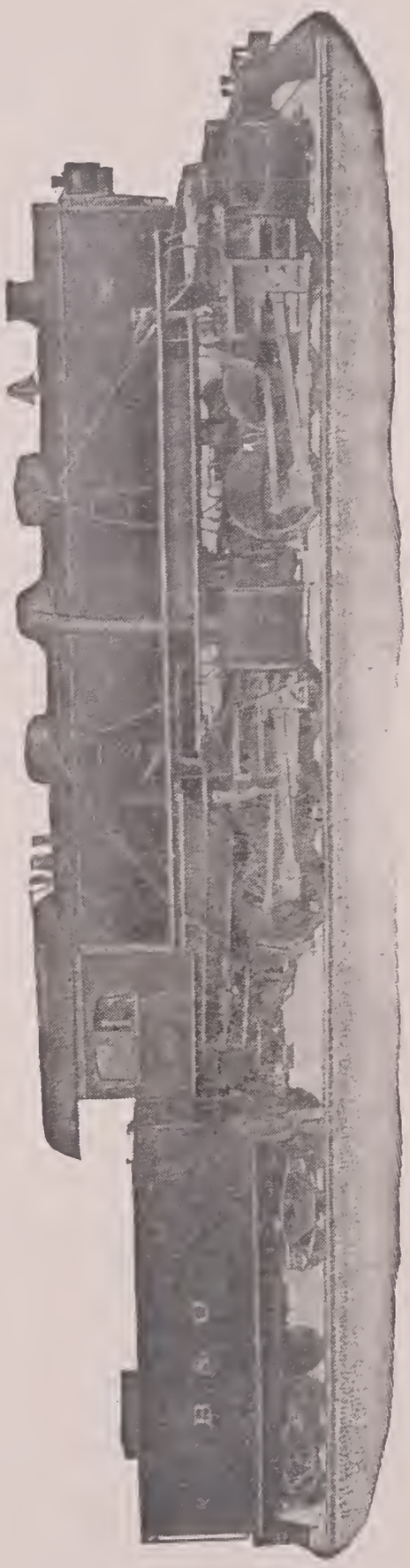


Fig. 23.

"In Fig. 23 is shown a Mallet articulated compound engine built for the Baltimore & Ohio Railroad in 1904. This was the first engine of this type in America, and at that time was the heaviest locomotive in the world. It was also the leader of the introduction of the Walschaert valve gear into regular American railway service.

"Fig. 24 shows the engine which at the present time holds the record as being the heaviest and most powerful locomotive in the world. This engine has a total weight of 410,000 pounds and will haul a train of 2,600 tons on a 1.3 per cent grade. It is one of three of the articulated compound type built for the Erie Railroad which are now operating in pushing service on the Susquehanna Hill, between Susquehanna and Gulf Summit.

"These illustrations serve to show that the Walschaert valve gear may be applied to any type of engine without any material change in the design or multiplication of the moving parts, and this adaptability is one point in its favor over the Stephenson link motion. The essential difference between the Walschaert and the Stephenson types of valve motion is that the former gives the same lead at all cut-offs; while, with the usual construction of the latter, the lead increases as the reverse lever is hooked up. The accessibility of the Walschaert valve gear is an undisputed point of advantage, which recommends it to all railroad men; and the fact that the Walschaert valve gear is increasing in favor with those roads that already have engines equipped with it, and that other roads show a willingness to try it out, would indicate that this valve gear will soon be more generally used in this country than the Stephenson link motion."

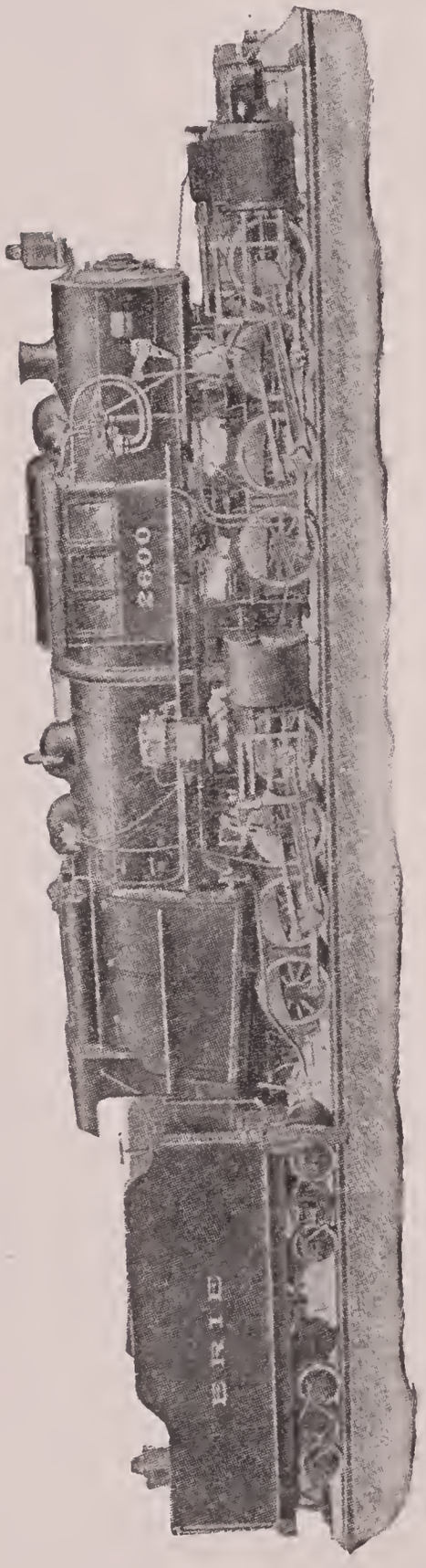


Fig. 24.

TO ELIMINATE DENSE SMOKE.

One leading railroad has recently issued the following instructions to its enginemen, governing the firing of locomotives for the suppression of dense smoke:

1st.—Engineers will be responsible for the proper operation of locomotives with respect to the handling of the reverse and throttle levers, and the supplying of feed water.

2d.—Engineers and firemen will be equally responsible for the operation of the steam blowers or smoke suppressors and for the smokeless and economical method of firing locomotives in accordance with the following general instructions.

3d.—Before the commencement of a trip or day's work the rocking and drop grates, ash pan dampers, ash pan slides and steam jets, and grate and ash pan operating gear should be examined and tested to see that all grates set level when latched and that all parts are in good working order and in proper position. The smokebox and ash pan should be clean and the smokestack and ash pan steam blowers in good order. All necessary fire tools must be on the locomotive. The fire must be put in good condition on the grates by spreading and replenishing with fresh fuel, in small quantities at a time, until properly built up preparatory to starting with a full supply of water and steam in the boiler. The coal on the tender should be wet down.

4th.—Lumps of coal should be broken to as near the size of a man's fist as consistent before putting into the firebox.

5th.—A thin, clean fire should be maintained so that the fuel can be supplied with sufficient air through the grates for proper combustion, and produce a clear, bright flame. Cross firing should be practiced to maintain an even bed, free from holes, and localized heavy or lumpy firing should be avoided, as the latter method does not permit sufficient air to pass through the fuel and results in dense smoke and clinkers. The use of the rake and "puddling" of the fire should be resorted to only when absolutely necessary to spread an uneven fire caused by uneven draft or improper firing. The banking of green fuel at the furnace doors should be restricted.

6th.—The grates should be kept well supplied with coal at the sides, ends and corners of the firebox, and not more than two or three shovelfuls, each scattering the coal, should be supplied at one time. Heavy intermittent firing should be avoided. Only sufficient fire should be kept on the grates as is necessary to prevent loss of heat on account of cold air passing through the grates so freely as to reduce the temperature of the gases, and to suit the way the locomotive is being operated.

7th.—Injectors and reverse and throttle levers should be operated to favor the firing when starting from a station and on heavy pulls. The smokestack blower should be used when necessary to prevent reduction in boiler pressure, and the boiler feed should be increased to prevent release of steam through the pop valves.

8th.—Previous to the closing of the throttle valves the fireman should apply the steam blower or smoke suppressor to such an extent as practice may demonstrate is necessary to suppress smoke. When locomotives are working steam, the smoke suppressor should be used

lightly. The supply of steam to the air induction jets should be regulated by the size of the opening in gasket, so that on locomotives not equipped with brick arches there will be no tendency to blow the smoke to or through the flues.

9th.—Rocking grates must be shaken lightly and frequently, instead of violently at long intermittent periods, and, if possible, when steam is shut off. As a general rule all rocking grates on passenger locomotives should be shaken every 30 miles, on freight locomotives every 15 miles and on switching locomotives every three hours. This practice will break any clinker that may be forming over or hardening between the grate openings, and will allow dead ashes to fall into the ash pans and keep the grates and fire clean. It will also allow air to pass through the grates and fire, and prevent the formation of clinker on the firebox flue and crown sheets, which occurs when air can not get through the grates and must pass over the fire.

10th.—The practice of opening the furnace door unnecessarily should be avoided, and firemen must regulate the ash pan damper openings to suit the requirements. When locomotives are drifting the fire must be maintained in a clean and bright condition over the entire grate area, more especially at the flue sheet.

11th.—Hopper slides of ash pans must not be opened when the locomotive is running. Ash pans and fires should not be cleaned near any frog, switch, crossing, derail or wooden building or structure.

12.—Certain fuels and locomotives will require special treatment, but in general the above methods are those of the most successful firemen, and the highest type of fireman is one who can maintain the working

steam pressure within a range of ten pounds variation with the smallest amount of fuel and the least waste of steam through the pop valves.

13th.—Exhaust nozzle openings and draft appliances must be adjusted to suit the winter and summer conditions, and when necessary on account of change in quality or kind of fuel furnished.

14th.—Engineers must immediately report any irregularities in connection with the cleaning or building of fires at terminals. They must also report defects in connection with piston or slide valves; cylinder or rod packing; dry, steam and exhaust pipes; smokebox draft appliances; stopped up or leaky flues; rocking and drop grates; ash pans and dampers; smokestack and ash pan, steam blowers and smoke suppressors, and all other auxiliary equipment pertaining to the economical use of steam and fuel, and for the prevention of dense smoke. All adjustments or repairs that may be found necessary must be promptly and properly made.

15th.—The company has been and is now expending a considerable amount of money to put machinery, boilers, fireboxes, flues, grates, ash pans and draft appliances of locomotives in a substantial condition for service, and with the grade and quality of coal supplied it is expected that some returns in fuel economy through proper methods will result from the operation and firing of locomotives. Passengers and the public at large are also entitled to consideration, and the elimination of dense smoke will contribute to their comfort, as well as to reduced steam failures and waste of fuel.

TO DISLODGE SNOW FROM FRONT CAB WINDOW.

The difficulty encountered by an engineer on account of snow driving against and sticking on the glass in the front of a cab is well known and it is not uncommon to see an engineer wipe away this snow frequently within a comparatively short space of time, during a heavy fall of snow. Some method by which this snow could be removed without the necessity of opening the door would be commendable and it would seem that an occasional blast of air drawn from the line supplying the brake system would be effectual. While there is no information at hand that such a device has been tried the idea would appear practical.

The necessary piping and connections would be simple. An arrangement of piping and controlling valve similar to that operating the air sanders would suffice and by connecting with a vertical pipe placed along the front of the cab parallel with the door, and provided with a line of perforations, a sudden blast of air could be directed against the glass whenever desired, with practically no exertion on the part of the engineer and without requiring him to leave his seat.

Mechanical devices, operated by systems of levers, for scraping away the snow, have been suggested; but these have not proved successful. Jets of steam would not be practical, as the steam would condense and the water of condensation would freeze upon the glass and thus coat it with a sheet of ice which would be as objectionable as the accumulation of snow. The use of air, then, seems to lend itself readily in this connection.

HEADLIGHTS AND WATER GLASSES.*

There are headlights and headlights, or, in other words, two headlight reflectors that are apparently the same as far as the general condition of the reflectors themselves, the burners, the wicks, buttons and ventilators of the cages are concerned, and one will be found to give a better light than the other, but this is not strange when it is noted how often one hears one locomotive being quoted as being so much better than another of the same class and specifications.

Silver or aluminum is used to coat the interior or headlight reflectors, to reflect or throw back the rays of light given off by the flame. Silver is really the best as it is a white metal, is soft and polishes well, and being so white of itself absorbs but little light.

The best reflector possible should be used with an oil headlight, as the view of the engineer behind the light is none too good at the very best, it seeming to serve more to tell the other fellow he is coming, and where he is, and to guide him safely through the yards at low speed than to be of any real benefit as an accident preventer when out on the main line flying along at a high rate of speed.

With the electric headlight the engineer's view is greatly increased, but the one toward whom the electric headlight is approaching finds it impossible to judge the distance of the coming headlight with any degree of accuracy.

*W. L. French.

It is an axiom of geometry that the angle of incidence is equal to the angle of reflection, and applying this to a headlight it means that the rays of light cast by the flame of the headlight on the reflector will be cast back at the same angle. The idea then is to so design the reflector as to collect and focus the greatest possible number of rays of light on the track ahead of the locomotive.

The reflector is made cone-shaped with the point of the cone cut off and rounded. Some roads set the glass in the front of the cage sloping in at the bottom, with the idea that the light will be thrown the better on the track, but it is doubtful if such is the case. The headlight reflector should be in line with the track and square with the glass in the cage to give the best lighting result.

A wick that is not charred or corroded is necessary for a good light, and the burner also should be clean. Cotton flannel will make a good wick, when a regular felt one can not be obtained, if fastened to the wick thimble in the same manner as the felt one. A wick can be trimmed by heating a piece of flat-iron, removing the button and burner, and burning the wick off smooth with the tube by laying the hot iron flat on the top of the end of the wick, or it may be trimmed off with a very sharp knife blade.

A wick that has been used can be trimmed in a perfectly satisfactory manner by running the finger around the top of the burner tube, being careful to move the finger always in the same direction; this will give an even surface to the top of the wick by removing all the charred wick. This method is quick and always available. Turning the wick up or down unnecessarily should be avoided, as it tends to make the wick ravel and be-

come uneven. The flame should be blown out and not turned out. The burner strainer should be kept clean so that air can reach the flame freely, as that is needful for a good white light. The height of the button above the burner has much to do with affording a good light by spreading the flame properly, and it also has something to do with the headlight smoking. If the headlight smokes when plenty of air is admitted to the cage, and the top of it is not stopped up with soot and the meshes of the strainer are open, raise the button on its spindle or, if it will not move, get one with a longer spindle and note the effect. Two or three trials may be necessary to secure the desired result. The slide at the bottom of the burner must be kept open and plenty of air be allowed to pass through the burner, as this will keep the chimney from becoming overheated and cracking or melting. The slides in the side or bottom of the cage should be so regulated as to admit the proper supply of air. Lamp black wet with signal oil and rubbed on with clean soft waste free from wiry material should be used to clean the reflector. The lamp black should be rubbed on lengthwise of the reflector and not around it. Polish it with dry lamp black and clean waste. Metal polish of any kind should not be used, for it destroys the silver coating on the reflector.

Headlights on large engines are placed too high from the ground to give good lighting results. Placed on the smokebox door of a "battle-ship" the headlight would be none too near the ground, and in no more danger of injury from anything striking it than it would be on the top of a smoke arch of a standard engine.

To light a headlight when a wind is blowing, take an ordinary train order, roll it in the form of a tube and

insert it in the top of the chimney, allowing the lower end of the order to rest on the wick inside the burner. Close the cage door, all but just room for the arm, light a match, and set the top of the order on fire. The blaze will run down the order and ignite the wick and one can close the door as soon as the order is lighted, as the light ash of the order will rise and float out of the chimney when the engine gets in motion. A headlight can be lighted in this manner in any kind of a wind.

The water glass has come to be regarded as a part of the necessary equipment of a locomotive, as it furnishes an accurate and easily observed notice of the water level in the boiler so long as it is kept in good working order, but the proper working of any device is, of course, dependent on that condition. The one thing to do to be sure that a water glass is in good order is to note if the water in the glass moves freely up and down; to do this the water should not be allowed to get up out of sight in the glass. More boilers have been burned on account of water being up out of sight in the glass and there being supposedly plenty of water in the boiler than from any other cause. If the water does not work freely in the glass, find the trouble and remedy it. It is when one thinks the water is all right, and it is not, that boilers are burned, for when the water is low and one knows it, proper precaution will always be taken to prevent any damage to firebox or boiler. A new water glass should be put in about every four weeks, as the action of the steam causes them to become thin at the top, and after that length of time where an engine is in active service a glass is liable to give away at any time. Putting in a new glass will prove to be a better safeguard to avoid

injuring any one than are the screens over the glass or wings on the water glass lamp.

When a water glass breaks, shut off top and bottom water glass cocks and open blow-off cock to water glass. This will remove any water remaining in the bottom nut. Remove packing nuts and packing nut sleeves, and clean out the old gaskets and broken glass from water glass cocks. Take plug out of top of upper water glass cock, pass water glass down through top cock and put on a rubber gasket or two if needed, put sleeve on, and then upper and lower packing nut, and lower sleeve with one or two gaskets as desired. Force glass down to its place in lower water glass cock, crowd gaskets in place, and screw packing nuts up firmly with the hand. Compressing the cold gaskets up tight by using a wrench on the packing nuts kills the life of the rubber, for as soon as the steam and hot water reaches the gasket they become hot and try to expand, and sometimes the rubber forces itself under the end of the water glass and stops it up, requiring the work to be done over. Replace plug in top of upper water glass cock, open both water glass cocks a little and close water glass blow off. Then open water glass cocks as wide as wanted. Blow the water out of glass and note how rapidly it returns. This will indicate the working condition of the glass and removes any small piece of rubber or glass that might have been left in the water glass cocks. If a water glass is too long it can be cut easily in the following manner: Light a torch. Take a common parlor match, dampen the phosphorus and rub it in a circle on the inner side of the water glass, where it is desired to cut it. When a good ring of the phosphorus shows on the inside of the glass, hold it where marked in the flame of the torch, rolling the

glass over in the fingers so that it will be exposed all around to the flame, and in a very few seconds it will crack off smoothly where marked. This is an easier way than to cut a glass with a file or a cutter, and it avoids the carrying of either of them, while a match is always available.

The fact that a water glass breaks soon after being put in is no indication that the glass was a poor one. The top and bottom water glass cocks may not have been in line, thus causing a side strain on the glass.

There is danger of injury to persons from flying glass when a water glass bursts, but putting in a new glass before the old one is worn to the bursting point is the better way.

A water glass will often show that it is in poor condition by indications of wear about the top of the glass, and it also appearing to contain flaws. Automatic devices to shut off the water and steam when a glass breaks are plentiful, but not very satisfactory in actual service as corrosion spoils their efficiency.

Most guards used interfere with the view of the water in the glass, and also with cleaning it. Some roads use an extension on the top packing nut that comes down nearly one half the length of the glass, the idea being to safeguard the part most liable to breakage and also to cause the engineer to carry a water level that will not be too high for the working of dry steam. These extension nuts are used on large engines.

The fireman has a good opportunity to note the water level at all times and to so carry his fire as to avoid a waste of fuel. If he did not know the true water level, naturally he would play on the safe side and carry a fire that would allow the boiler to be filled up when steam

was shut off. In addition the fireman is watching the water level as well as the engineer, and the chances of injury to the boiler by burning are greatly lessened, as the chances of two men overlooking the same thing at the same time are very few. In case it should be found that the water is not working freely in the glass the gauge cocks should at once be tried to determine the true water level, and it being found to be at a safe point blow out the water glass thoroughly. If that does not make it right, close top water glass cock, blow out the glass and open the top cock; proceed the same with the bottom one and then open them both and blow the glass out good. This will usually put the water to working freely in the glass; if it does not, the stoppage is pretty solid. A new glass can be put in, and if this does not remove the difficulty the engine will have to be run to the terminal, using the gauge cocks, and have the water glass boiler passages bored out after arrival.

Where the water is "bad," or much soda ash is used in the water, the water glass is of great benefit in fixing the true water level. By easing off the throttle the engineer can determine how much water he has at any time by allowing the foaming mass to settle. Where water is foaming the water glass should be blown out more frequently than with good water. The water glass should be located so as to be plainly visible to both the engineer and fireman, and if necessary to do this two water glasses should be used and a close watch should be kept on the water column at all times, and it is well for the fireman of today, who will be the engineer of the future, to make this an important part of his training.

INJECTORS.*

If the locomotive engineer of today was required to go back to the water pump as a means of supplying the boiler of his locomotive with water, he would rightly think that it was a long step backwards, and yet it is not quite half a century since Henri Gifford was granted letters of patent on the injector now so universally used to supply feed water to boilers.

From a theory this French engineer had worked out a practical instrument, the principle of action of which remains the same and the main working parts of which are practically the same.

To the man entering railway service in the last few years the pump seems to have been an instrument of the long ago, yet a third of a century would mark its more general application to locomotives, and then it was customary to place an injector on one side and pump on the other, and often the injector was allowed to lie idle, the runner preferring the pump. One of the great troubles with the first injectors on locomotives was their becoming hot and refusing to prime, or the feed water becoming too warm, and many a pail of cold water has been poured over the early injectors to cool them, when the men trying to operate them were about as warm as the injector.

Injectors may be classed as the single jet injector, double jet injector, and automatic injector. They may be of either the lifting or non-lifting type.

Single jet injectors are those using a single set of combining and delivery tubes.

*W. L. French.

The double jet injector contains two sets of nozzles, one set receiving the feed water and passing it on to the second set, where it receives the force that puts it into the boiler.

The automatic injector renews the supply of water to the boiler where the flow of feed water from the tank has been interrupted without the injector being shut off.

A non-lifting injector is one that is located below the bottom of the water level in the tank, so that the supply of feed water flows to it.

The lifting injector is placed above the tank and the water is forced to it by the air pressure in the tank; when the overflow is opened the steam forces the air out of the injector and overflow pipe and the air pressure in the tank forces the water up into the injector. The higher the atmospheric pressure the better the injector will work. Air leaks to injectors should not be allowed.

The important parts contained within the body of the injector are the combining tube, suction tube, delivery tube, overflow outlet and steam nozzle. The combining tube is the one in which the steam and water combines, and from which fact it receives its name. It extends from the delivery tube to the steam nozzle. The steam nozzle guides the motion of the admitted steam jet.

The delivery tube is the one in which the combined steam and water receives its greatest velocity before it passes to the branch pipe on its way to the boiler. In the branch pipe it loses a portion of its velocity. Owing to the velocity of the water through this tube it becomes rough and wears out sooner than the other tubes of the injector. It may be reamed out smooth, and used much longer by doing this, without renewing. This reaming

or boring out of the tube can only be done to a limited extent, for if the tube is enlarged too much the injector will not work with high steam pressure, the water not receiving velocity enough to overcome the boiler pressure. The suction tube extends from the upper overflow to the lower end of steam nozzle, and aids in starting the injector.

The overflow is an opening from the injector into an overflow or waste pipe when injector is being started. When the overflow is opened a small amount of steam escapes through the combining tube and overflow chamber and out of waste pipe to the atmosphere, and this creates a vacuum above the water in the feed pipe, allowing the air pressure in the tank to force the water up into the injector; if it is a non-lifting injector the water of course will flow down to it. The water enters the large end of the combining tube around the steam tube, and, steam being turned on, as the water and steam combines the jet of steam becomes smaller until it can enter the small end of the delivery tube, where the force of the jet being concentrated on a small opening it gains its greatest velocity, and is able to raise the check and enter the boiler against boiler pressure. The weight of an object multiplied by its velocity in feet per second will give its momentum. The steam and water combine their weight and velocity and thus gain the momentum or force needed for the injector to work.

The maximum capacity of an injector is the greatest volume of water passing through the delivery tube in a steady flow with any steam pressure. The minimum capacity is the least water passing through the delivery tube without loss at the overflow. The range of an injector

is the difference between the maximum and minimum capacities of the injector.

It is necessary that the water be cool enough at all times to condense the steam, and the time for this condensation is very short, just while they are passing through the combining tube, so that there must be enough difference between the temperature of the two bodies for the steam to condense quickly. If not, the volume of steam will be too great to enter the delivery tube. Where the feed water is too warm the injector will not take up all the water, that is, a certain amount is wasted at the overflow pipe opening, or if too hot the injector will not start to work at all. If there was more time for the combining of the water and steam no doubt injectors would work with feed water at a higher temperature than they will at present.

Feed water that contains lime or sand wears rapidly on the combining tube. Water heavily charged with lime corrodes the interior of an injector quickly and puts it in a condition in a short time that it will not work.

In locomotive service the difference in the water supply on a single division of a road may be great, making a hard condition to overcome, as often the water that can be obtained must be used, as there is no choice on account of the limited supply at certain points. This has led to the establishment of plants for treating or softening water at certain points by the use of chemicals, with marked benefit to both injectors and boilers.

A non-lifting injector will not corrode in bad water as quickly as a lifting injector, for it is less subject to the action of the steam. If the throttle on the boiler head or steam fountain to a lifting injector was closed when the injector was not in use the injector would not

require an acid bath so often. This is particularly true of the one not in active use. The steam seems to form the scale on the tubes and interior parts of the injector the same as it does on the interior of a tea kettle.

There are two prime defects to an injector: one, failure of the injector to lift the water; the other failure to force it all into the boiler. There are several things that would cause one of these conditions aside from wornout tubes.

If the boiler check does not raise enough, or the branch pipe does not have sufficient area to care for the water delivered to it, part of the water might enter the boiler and part of it be thrown out through the overflow pipe onto the ground. A boiler check might become corroded or the space about it become filled with "mud" and cause it to get in this condition. Branch and feed pipes, as well as tank hose, goose necks and tank valve openings, should be large enough to furnish or care for all the water used by or delivered by the injector. Putting on injectors of large size capable of delivering a large amount of water to the boiler will not give good results if capacity of connecting source of supply and delivery are not increased in the same proportion.

Overflow pipes should not be too small, and they should be so made that there will not be any short bends in them to retard the flow of the water when injector is priming. As a rule an injector does not get out of order quickly or easily when one considers the amount of work one of them does, and if given proper care will give good service for a long time, and nothing is more important about a locomotive than good injectors that can be relied on to work properly whenever needed.

In case the throttle of an injector leaks, dry steam only

will show out of the overflow pipe. The fact that it is the throttle that leaks can also be determined by shutting off the source of supply at the steam fountain. If the boiler check leaks, steam and water will both escape from the overflow pipe, but the same is true if the injector primer leaks. By closing the stop cock to the boiler check it can be easily shown whether it is the boiler check or the primer that leaks. If boiler check is not provided with a stop cock open the front pipe valve to the check, and if steam and water comes out of the front pipe it is a good indication that it is the check that leaks. A leaky primer will not prevent injector working if it can be made to prime. If check or throttle leaks so that a vacuum can not be formed injector will not work, for feed water will not raise to it.

Sometimes an injector with a leaky throttle or check can be made to prime by opening the throttle a turn quickly and at once shutting it off. This blows the hot water out of the supply pipe and gives a chance for a vacuum to be formed, and the feed water rising, the injector will prime and can be put to work.

When a restarting injector breaks, owing to low water, rough track or any other temporary cause of interference with the source of water supply, the steam from the throttle is carried away from the feed pipe and the water coming back to the injector it again goes to work.

Any foreign substance in the tank that gets down about tank valves or into tank hose will interfere with the working of the injector, or perhaps cause it to fail altogether. Close the heater plug down so that steam will not blow out of overflow pipe and open injector throttle; this will usually blow the obstruction away so that one can get along until terminal is reached, when the foreign

material can be removed from the tank. In case it does not remove it, take down tank hose, remove strainer, and open tank valve and wash hose out. This can be done at the first stop if the other injector is working good, as it is always desirable to avoid delays. Air leaks in pipes between injector and tank will cause injector to fail to work ordinarily. With a full or nearly full tank of water it may be got to work, but even then it will likely break at any moment. Closing the tank valve and the overflow and blowing some steam back into the pipes will locate the leaks. Too much steam must not be blown back or hose will be blown off or bursted.

If the combining tube gets stopped up, shut steam off from injector. Remove injector throttle, and with a wire remove obstruction from tube. This defect is not of ordinary occurrence. If small valve on end of steam throttle comes off stem, shut steam from injector, remove throttle and put valve back on spindle. This is a short job ordinarily. To prevent overflow pipe freezing in the winter when using a heater, leave joint to heater valve open a little so that a small amount of steam will escape out of overflow pipe, or open primer occasionally. The former is the best method, as one is apt to forget the primer too long. There is always a loss of heat in working an injector, and its throttle should only be opened sufficiently to supply enough steam to keep injector working properly.

THE QUICK DISPATCHING OF ENGINES AT TERMINALS AND HOW TO HANDLE MOST ECONOMICALLY.*

The question of quick dispatching of engines at terminals is a very live subject, and a very important factor toward successful railroading.

The management of the various railroads of today want all the power possible to be in continuous service, earning dollars and cents, instead of lying idle in the round-house at the various division points. The question is: How shall this be accomplished in the shortest given time?

There are several important features that must play a part in this, viz.: Advance information, harmony, efficiency, promptness, aggressiveness and well planned and arranged conveniences.

Advance information: The round-house foreman should keep in close touch with the train dispatcher, as to what engines are coming in, and what time they are expected. The round-house foreman should also be advised in advance of the nature of repairs that might be needed upon the arrival of the engine, provided the repairs be other than ordinary running repairs. This will enable him to get a line up of the material needed and distributed to the various departments, and have it advanced as much as circumstances will permit.

Engineers should lose no time upon arrival in examining their engines, and make their report, reporting only

*William Hall.

such work as is necessary, thus enabling the round-house foreman to get his work-slips lined up by the time the engine reaches the house. The engine inspector should be alive to the situation, and can be of valuable assistance to his foreman by getting his inspection done immediately when the engine arrives. He should be on the lookout for engines coming in, so that no delay will be caused by his inattention to business.

Perfect harmony should exist at all times between the train dispatcher, round-house foreman and the heads of the various departments; all friction should be eliminated, and each one should be loyal enough to work for, and advance the best interest of, the company employing him.

An efficient organization is quite an important factor in the quick dispatching of engines, and should be able to cope with the situation at any and all times. The round-house foreman should have an assistant outside, having charge of the dispatchers, clinker-pit force, table men and common help around the house. With a live man in this position some wonderful results can be accomplished. He should relieve the foreman of the supervision of dispatching engines and other outside work, thus enabling him to keep in close touch with the force doing the repair work.

The outside assistant should be notified as to what engines are wanted first, such engines as are wanted in specified stalls, engines wanted in without coal, sand or water; also be furnished with a list of engines due for wash-out each day, and if he be a live man he will immediately notify the round-house foreman every time an engine due for wash-out comes in, and find out if he should put her in the wash-out stall or not. Telephones should

be used wherever practicable, as many steps and much time will be saved by their use.

The foreman and his assistant should keep in close touch at all times; in fact, the foreman should give his assistant a general line-up from time to time as conditions change.

Engines from the time of arrival to the time of leaving should receive prompt attention from all concerned, working on the "Do It Now" principle, and not putting off till tomorrow what can be done today.

There should be sufficient force of men to accomplish the desired results, and here is where the outside assistant can get in his work by seeing that engines are not kept waiting to be dispatched.

Upon the arrival of an engine at the terminal she should immediately be taken in charge by the dispatcher, who should see to it that the boilers are filled with water, provided there is no boiler work to be done or flues caulked. He should examine the fire-boxes while the fire is bright, and if everything is all right he should consult with the assistant as to whether the fire should be knocked out or simply cleaned. If no boiler work is to be done the fire should be properly cleaned, thus saving contraction of the flues, also saving time and fuel.

Now, as to the conveniences, these should be so well planned and arranged that there should be no reverse movements of an engine. There should be at least two or more tracks leading from the turn-table so that the outgoing engines will not interfere with the incoming engines. The turn-table should be operated by air or electricity, as the operation of the table by hand is old-fashioned and antiquated. Modern clinker pits should be used and conveniently located, the sand towers and

water tanks should be so located that the engine will be advancing with each operation.

The round house should be well lighted and ventilated, as men will work to better advantage. It would also be a good plan in large and busy round houses to divide the force so as to work the full twenty-four hours, thereby taking care of the running repairs promptly and avoid holding the engines over. Engines that need more than is commonly known as running repairs, however, should be held over for the day force, when the round house is backed by the machine shop, blacksmith shop and boiler shop, this work being done more cheaply in the day time than at night.

By this plan of taking care of engines during the entire twenty-four hours a larger number of engines can be had for the prompt movement of traffic.

All round houses should have a few machine tools, so that if it is necessary to drill a hole, turn up a bolt, or any small job, it will not be necessary to start up the entire machine shop; or if this is not practicable a few tools should be grouped in the machine shop and run with a line shaft, connected with an independent motor. This should be so arranged that the motor should be used only at night, the shaft being driven from the main shaft during the day.

When engines are held in for other than light repairs, and after being re-examined by the inspector, the round-house foreman should look over his work reports; work which requires the assistance of the machine shop or other departments should be removed and taken to the respective departments at the earliest possible moment so as to give them a chance to get their work done without delay to the round-house force, thus working hand in

hand with each other. The foreman of each department that has work to do should be notified of the time the engine is expected to leave the house, so that they may be governed accordingly, always giving running repairs the preference.

Wherever it is practicable separate stalls should be used for washing-out purposes as it does not interfere with the rest of the round-house force while engines are being washed out. These stalls should have good drainage.

A hot-water plant is a very necessary adjunct to a round house, as by the use of hot water for washing-out purposes the boilers are not subjected to such severe strains due to expansion and contraction as when washing out with cold water.

The hot water could be used for filling up the boilers after they are washed out, so that an engine can be gotten into service in the shortest time possible.

Harmonious co-operation between the mechanical and operating departments, especially during periods of congestion, or when power is in great demand, will facilitate matters greatly, and be a great factor in accelerating the movements of engines at terminals.

An aggressive progression policy should be adopted by each and every one, each man putting it up to the next one to see that no delay is caused through his negligence.

ROAD FOREMEN OF ENGINES AS FACTORS IN NET EARNINGS OF RAILWAYS.

"The road foreman of engines occupies in reality an important position in the railroad organization, for there is probably no one element which enters more largely into the railroad's cost of producing what it has to sell, viz., the transportation of freight and passengers, than the movement of trains," said James McManamy in a paper read before the Traveling Engineers' Convention in 1908. He stated that "the cost of moving passengers per mile or the thousand tons of freight per mile is affected largely by the manner in which the power is handled, and it is largely the duty of the road foreman of engines to get out of the power the possible one hundred per cent. of its revenue capacity. It is generally conceded that a freight locomotive should make an average of not less than 30,000 miles per year. We will assume that the average freight carload is twenty tons per car. Let us consider the net result to the railroad if through the careful guidance of the road foreman of engines one additional car can be added to the train. This would increase the tonnage revenue of the locomotive 600,000 tons one mile per year, and assuming the average returns to the railroad to be one-half of one cent per mile, we have increased the revenue of each locomotive $300 per year.

"'Can't' is the unfortunate attitude of thought held by a large number of men, and all of us have met in our experience this ready 'can't' each time we have presented to others some such possibility as above stated." He

stated that he had not overlooked the fact either that on some lines the tonnage question had been carried to an extreme, and that the power has been so completely overloaded that in the effort to move tonnage the reverse condition often resulted, and unfortunately on those lines two extremities have met with disastrous results to the net earnings of the railroads. One side has insisted upon the enforcement of the exaggerated idea of tonnage per train, with the result that trains actually spend more time on sidings than is required to cover the distance between terminals, and at the same time those trains consumed more time waiting for orders than the actual running time required between the terminals. In other words, more time is lost on sidings and waiting for orders twice over than is required to cover the distance between terminals, and he rather questioned the economy of such operations. But on the other hand he did not justify the attitude of the other extremist, who always insists upon "can't" and therefore does everything in his power to defeat the other plan by increasing the delays above stated.

"In all of my railroad service," said he, "I have insisted there is only one department on a railroad, and that is the department of profit or loss, and it is therefore the sole duty of every officer of the railroad to let the idea of increased net profits be the mainspring of each act as relates to railroad operation. Therefore, there should be no opposing influence between those connected with the motive power and those who are giving their undivided time and attention to the matter of transportation. There should be no conflict between those at the head of the motive power and those at the heel of transportation. There should be a close co-operation between the road foreman of engines, train masters and train dispatchers,

and each should be perfectly willing at any and all times to set aside his personal opinions in deference to those of the other in an earnest effort to bring out the highest possible good for the railroad as a whole. This statement applies to every person in the employ of the railroad from the highest to the lowest, and working along these lines I do not hesitate to say that there are thousands of locomotives in service today that will easily handle one more car per train than they are hauling now on an average year in and year out, and if properly kept moving will handle one train more each month instead of consuming this time on side tracks. Dispatch is just as valuable to the shipper as a lower freight rate, and he will always patronize the road that delivers the goods to him with the least delay."

"The road foreman of engines and those whom he represents can do a great deal toward drawing the line of consistency between prudence on one hand and overloading the locomotive on the other, and in this way will be able to get the locomotives over the road with less delay and get them into terminals where they can receive proper attention in the way of necessary work and with very little delay have them ready for another successful trip, all of which proves economical in the cost of maintenance and fuel and he will thus be enabled to greatly increase the miles per locomotive in his charge.

"This means more tons of freight over the road in a given time with the same number of locomotives, and less cost per ton mile. Nothing requires more careful thought and closer co-operation between the road foreman of engines and the transportation department than this one question. By taking hold of this problem with a determination to improve conditions, you can do a great

deal toward solving the transportation problem and increasing the net earnings of the railroad. The road foreman of engines can do a great deal to reduce the cost of production or increase the net earnings by properly educating the men under him.

"The factor of safety is of the first and greatest importance and requires constant vigilance on the part of all concerned to avoid accident to passengers and employees and damage to property; next in order of importance is economy in the use of fuel, oil and all supplies. This requires close co-operation between the road foreman of engines and the engineers and fireman and close attention to the making of steam and then avoiding its waste. The engine must be properly drafted, so it will steam well. Brick arches must be cleaned off and flues kept clean. Keep all leaks out of the fire-box and plug up every other leak around the engine. I might add here that many road foremen of engines would be surprised if they knew the actual loss by leakage on the locomotive; in other words, the surplus steam the locomotive has to make in order to have the amount necessary to do the work. The outside machinery will ordinarily be inspected. The valves, cylinder packing, front end, flues and firebox do not always get tested or examined until trouble of a serious nature exists. An engine with badly worn machinery that has a good boiler and uses the steam without leaks will handle a train fairly well, although it may take a little more coal. Yet the coal is doing the business because it is getting the train over the road, while the same engine with the ordinary leaks would burn more coal and not come near doing the work. In other words, any engine with the boiler kept in good steaming condition and without leaks

will after the first three-months' service out of the shop begin to increase its superiority over its sister engine that is cared for as many locomotives are cared for today, and it will increase its superiority day by day as the time out of the shop grows longer until finally when they go to the shop the first one will still be able to do pretty fair work while the other will be, in common language, 'ready for the scrap pile.'"

In the report of the Master Mechanics' committee that tested slide and piston valves for leakage in 1904, the following conditions are shown:

The best piston valves tested leaked 268 lbs. per hour and the worst tested at a mileage of 36,000 leaked 2,880 lbs. per hour.

The best slide valves tested at a mileage of 17,500 miles leaked 384 lbs. per hour and the worst tested at a mileage of 39,000 miles leaked 2,610 lbs. per hour.

LEAKAGE IN LBS. OF WATER PER HOUR.

	Least.	Greatest.	Average.
Piston valves, 14 engines.....	268	2,880	1,208.99
Slide valves, 11 engines.....	384	2,610	1,224.54
Average leakage, all valves, 25 engines		....	1,215.83

Average loss in coal for each engine per day, month and year, in both freight and passenger service, averaged at ten hours per day, evaporation figured at 7 lbs. of water to 1 lb. of coal. The figures are:

One Day.	One Month.	One Year.
1,736.9 lbs.	26.05 tons.	312.14 tons.

Average loss in dollars and cents per engine per day, month and year, coal figured at $1.90 per ton:

One Day.	One Month.	One Year.
$1.64	$49.23	$590.77

"The tests were made on two different railroads and with great care. The leakage was calculated by condensing the leakage steam and measuring it in pounds of water; the common snap-ring piston valve and the strip partially-balanced slide valve were the ones tested. Multiply these figures by the number of engines in your service and the result gives food for reflection. Note the mileage at which this appalling waste occurs. Then, if you can, just imagine or estimate the amount of this waste during the time and at which time the engine reaches a satisfactory mileage or period of service, it will give you a fair estimate of the amount of steam and fuel wasted on account of steam leaks in valves and cylinder packing of the average locomotive."

DEVELOPMENT OF MOTOR CARS, OR INTERNAL COMBUSTION ENGINES FOR RAILWAY SERVICE.

There is no longer any doubt as to the field for rail motors. They will become an important factor in light passenger service in the immediate future, many roads having several in service even at this early stage in their development.

It seems fitting, therefore, that in a work of this character some account of what has thus far been accomplished should be given. Accordingly the editors have compiled the following data upon the subject.

GASOLINE MOTORS—MECHANICAL TRANSMISSIONS.

Union Pacific.—In this country, the most extensive development work in the rail motor car field has been done by the Union Pacific railroad. That railroad has built a number of gasoline motor cars, all of which have direct mechanical drive.*

Their latest design of car, motor car No. 8, is equipped with a 200-horsepower motor, especially built for the rough service incident to use on suburban lines. The motor consists of six cylinders, 10 inches in diameter by 12 inches stroke. The total weight of the car is 61,300 pounds, equivalent to practically 300 pounds weight per horsepower. This car has, since last summer, been run-

*Report presented at annual convention, American Railway Master Mechanics' Association.

ning regularly between Beatrice and Lincoln, Neb.; it has shown remarkably uniform results and has materially increased the traffic between those two towns. Ten additional cars, similar to this successful model, are being built, as well as a number of trailers to be used in connection with them. Four regular branch line services have been maintained in Kansas and Nebraska, on the Union Pacific alone, during the severe weather conditions of the past winter, and with notable success. The motor cars have been remarkable in regularity of service, having demonstrated that they are even superior, in this respect, to the steam train service.

After two years of continuous service, it has been found that the average cost of fuel the year around, taking into consideration both summer and winter conditions, using 72-degree gasoline, amounts to 3.5 cents per car-mile. As a substitute for gasoline, California distillate has been used in regular service with gratifying results. Obviously, the cost per car mile is thereby greatly reduced, as the distillate is a much cheaper product than gasoline. Some interesting experiments have been conducted with the motor of car No. 8, using denatured alcohol as fuel. The results were very satisfactory; in fact the newest type of motor (No. 8) gives equally as good performance with that fuel as with gasoline.

"Sunny Brook."—A light railway motor car, the "Sunny Brook," has recently been built at Indianapolis, Ind., for service in Yellowstone Park. This car has a four-cylinder gasoline motor, cylinders 6 by 6 inches, the engine developing 50 horsepower at 700 revolutions per minute. The car is built after the conventional street car design and weighs 30,000 pounds. It is asserted that,

at full speed, the car can attain thirty-five miles per hour. The transmission is of the mechanical type with three speeds forward and three reverse, with chain drive of the Renold silent chain type.

GASOLINE MOTORS—ELECTRIC TRANSMISSIONS.

Strang Cars.—Another example of gasoline rail motor cars in successful operation is the Strang Car, mentioned in last year's report. Three of these cars are in regular operation between Kansas City and Olathe. The first one has been in continuous service for over a year, the second and third cars having been in operation between six and seven months. Other cars of this type are now under construction for use on several steam roads. The transmission used in the Strang system is of the electric type, the generator being directly connected to the motor, forming a self-contained generating unit. Directly from the brushes of the generator, main wires lead to a controller of the series parallel type. From this controller, wires lead to electric motors hung on the axles of the front trucks according to standard electric railway practice. In multiple with the wires between the generator and controller, is connected a small storage battery, and in one of the main wires between the battery and the generator is placed a rheostat, which is used for the purpose of temporarily converting the generator into a motor when starting the engine. The first of these cars weighs 78,000 pounds, and it is claimed that the gasoline consumption has averaged about .45 of a gallon of gasoline per motor car mile for a mileage of 60,000 miles. The largest and latest of the three cars is 52 feet 9 inches

long, weighs 84,000 pounds and has the following equipment: 100-horsepower gasoline engine, 50-kilowatt generator, two 65-horsepower motors and storage battery of 112 cells, with 250 ampere-hours capacity.

St. Joseph Valley Traction Company.—The motor car used on this road has been described a number of times in the technical press. It is of the gasoline-electric type and has been in actual daily service for two years. Within the past two months the equipment was destroyed by fire. The service of this car consisted in hauling from one to three trailers, three round trips per day, over a road eleven and one-half miles in length, making the half trip in thirty-five minutes with four stops, the heaviest grade being 1½ per cent. It is stated that the fuel consumption with one trailer was three-fourths of a gallon per mile. The motor consisted of a four-cylinder 70-horsepower gas engine direct connected to a 50-kilowatt, 250-volt generator in parallel with which was connected a battery. Four 50-horsepower motors were used on the trucks. Weight of motor car 70,000 pounds; trailer 38,000 pounds. Very satisfactory service results are reported to have been obtained from this car.

General Electric Company Car.—This company is now bringing out its second-rail motor car of the gasoline-electric type. While the system used is the same in both cases, the second car is radically different in both design of car body and the power equipment, and promises to give very satisfactory results. The car body is of steel, the ends being rounded to decrease wind resistance. The roof is of the Mann type, equipped with globe suction ventilators. The car body is divided into an engine compartment, baggage, smoking, main and toilet com-

partments, and operating-cab at rear end. It has a seating capacity of forty.

The equipment consists of an eight-cylinder V-construction gasoline motor of 150 to 175 horsepower, direct connected to an eight pole, commutating pole, 90-kilowatt generator with an exciter of 3½ kilowatts capacity, for the purpose of exciting the fields of the main generator, and effecting the variable potential control. From the generator leads are conducted to two 65-horsepower motors, situated one upon each truck of the car. These motors are always connected in parallel, the required torque or speed being obtained by varying the field current of the generator through the intermediary of a specially constructed controller, embodying essentially the required resistance suitably arranged in fifteen steps.

The gasoline motor is of the four-cycle type, equipped with two separate systems of ignition; one, the high tension using induction coil connected to a four-volt storage battery, the other make-and-break connected to a direct-driven Simms Bosch low tension magneto. The carbureter is of the single-nozzle hand-compensated type, gasoline being supplied to it by means of a diaphragm pump. Radiators for water cooling are located on the roof of the car. The circulation is by thermo syphon. The gasoline motor is controlled by one lever superimposed over the controller handle. The normal speed of motor is 550 revolutions per minute.

The car is heated by by-passing as much as required of the exhaust gases through pipes approximately in the same position as steam pipes in the standard railway coach.

An acceleration of a mile per hour per second is obtained to approximately twenty-five to twenty-eight miles

per hour. From this point, acceleration falls off gradually until full speed is attained at approximately fifty to fifty-five miles per hour. The total weight of the car is 60,000 pounds.

STEAM MOTORS.

Canadian Pacific.—In the steam motor car field, one of the noteworthy examples of original development work is found in the car designed and built by the Canadian Pacific Railway. This car was in operation all of last summer between Montreal and Vaudreuil, a distance of twenty-four miles, giving a service of three round trips per day, on a regular schedule, allowing one hour for the run out, including twelve stops, and the same on the return trip. It was popular with the passengers and gave fairly good satisfaction to the railway company.

The boiler is of the return tube marine type, carrying 180 pounds pressure, equipped with superheater coils and a Morrison furnace, brick lined; crude oil is used as fuel with a burner of the "Booth" type having a 1-inch slot.

The cylinders were originally turned out with bushes 10 to 15 inches, but after a time the bushes were removed, leaving the cylinders 11 by 15 inches. The valves, which are of the piston type, are fitted with Walschaert gear.

When the car was first put into service, 1.8 imperial gallons of oil were consumed per mile, but as the men gained experience in the handling of machinery, the consumption was reduced to 1.6 imperial gallons per mile; 5,000 gallons of water were evaporated per hour, giving a factor of one pound of oil to ten pounds of water.

Experiments have recently been made on the testing

plant at the Canadian Pacific shops with the same boiler and motor, using ordinary run of mine coal as fuel, instead of oil, with very satisfactory results, namely: during a test of one and a half hours, an average steam pressure of 172 pounds was maintained at a speed of forty-seven and a half miles per hour.

Total water evaporated, 8,569 pounds.

Water evaporated per hour, 5,720 pounds.

Total coal consumed, 1,300 pounds.

Pounds of water evaporated per pound of coal, 6.6.

Average temperature of gases in combustion chamber, 952° F.

Average temperature of steam at steam chest, 578° F.

Ganz Cars.—Motor cars of this type are being built for four different roads. All-steel construction is used for the body, which has a seating capacity for fifty-two passengers. Total weight of car in working order is 70,000 pounds.

The boiler or steam generator is of special design, carrying a working pressure of 270 pounds, the steam being superheated, capacity 120-horsepower. The steam motor is of the enclosed type with compound cylinders, all moving parts running in oil. It is mounted on the forward truck and drives the rear axle thereof through one set of gears.

This car is designed to maintain a speed of thirty-five miles per hour on a level track. Average fuel consumption is claimed to be from 10 to 12 pounds coal per mile.

The development of motor cars abroad has made greater strides than in this country. Numerous English and continental railway companies have permanently established rail motor car service in different localities with marked success. One may see such cars in opera-

tion on unimportant branch lines as feeders to trunk line trains; on main lines through thickly populated districts carrying passengers to and from more important towns served by express trains; on suburban lines in competition with trolley cars and steam trains and on an entire railway system where there is no other means of transportation except for heavy freight.

A brief description of the motor cars in operation on the principal railways of England and the Continent is given herewith, which will serve to show the development of this type of motor car abroad. It is not the purpose of this report to enter minutely into the details of construction, but rather to show up in a general way the present situation.

GASOLINE MOTORS—MECHANICAL TRANSMISSIONS.

German Daimler Car.—The German Daimler gasoline car has been used in considerable numbers on some of the smaller German railways, notably the Wurtemburg State Railway, and on the Swiss Federal Railway. It is a comparatively small car, having a total length of 33 feet, with a seating capacity of thirty-six. It is equipped with a 30-horsepower Daimler engine of the heavy slow-speed type, its normal speed being about 550 revolutions. The motor has four cylinders 5¼ inches diameter by 6¾ inches stroke. It is located in the middle of the car, attached to a sub-frame upon which the car body is supported by eight elliptic springs, the subframe being carried rigid on the two axles. Power is transmitted from the motor through a leather-faced cone friction clutch, and through a sliding gear transmission (arranged to give four speeds and reverse) to one of the axles. Con-

trol levers are provided at each end of the car, by means of which the speed of the motor, or the direction of motion, is controlled from either platform.

GASOLINE MOTORS—ELECTRIC TRANSMISSION.

Northeastern Railway Car.—About three years ago, the Northeastern Railway of England put into service two "petrol-electric" cars. The power plant consists of a four-cylinder horizontal opposed Wolsey gasoline engine (8½ by 10 inches, 85 brake horsepower at 420 revolutions per minute) direct connected to a compound wound, separately excited generator, of 55 kilowatts capacity, which furnishes current to two 50-horsepower electric motors, of the ordinary railway type, on the leading truck. The total weight, including 60 gallons of gasoline and about 100 gallons of cooling water, is 35 tons, of which 22 tons are carried on the power truck. These cars are used during the summer season only. Three and one-half car-miles per gallon of gasoline is claimed for them. As this particular type of car has not been perpetuated by the original builders and users, it is safe to assume that it is not entirely satisfactory. The enormous size and weight of the power plant and the space occupied (being about one-third the total length of the car) are undoubtedly the reasons for discontinuing the construction of this design.

Arad & Csanadar Railway. On the Arad & Csanadar Railway, in Hungary, a number of gasoline electric cars are used, the largest of which has a 70-horsepower gasoline motor direct connected to a 45-kilowatt generator, which supplies current to ordinary railway type motors attached to the two axles. The usual series parallel con-

troller is provided for starting. After the car is once under way, its speed is almost entirely controlled by the throttle of the gas engine. Controlling apparatus is provided at only one end of the car. The car is equipped with air and hand brakes, air being supplied by a small compressor driven from the outer end of the armature shaft. Jacket water from the motor is passed through coils inside the car for heating during cold weather. When no heat is required the water is passed through a coil of tubes on the roof. The space occupied by the power plant is considerably less in proportion to the length of the car than that of the Northeastern Railway, although the systems are practically identical in principle. The acceleration of the car is very good, its maximum speed is about thirty-five miles per hour without trailer. It is claimed by engineers of this road that 65 per cent of the motor's power is delivered at the wheels. Very satisfactory results are reported from these cars.

STEAM MOTORS.

Great Western Railway of England. One of the most satisfactory cars in operation abroad at the present time is the one developed by the chief engineer of the Great Western Railway of England. In the neighborhood of sixty of these cars are in service on various parts of the Great Western system, and others are in course of construction. They combine to a remarkable degree many of those qualities essential to success, namely, large seating capacity with only moderate weight, flexibility of control, reasonable speed and acceleration, reliability, low maintenance and fair operating costs.

The boiler is of the vertical, fire-tube type with no superheater, supported directly on the frame of the power truck and serving as a center pin by transmitting the driving effort to the sills of the car through flat springs. It is enclosed within a compartment of the car body (about 14 feet long) which contains coal bunkers, operating levers, etc. As the car is arranged to run in both directions and controlled from both ends, a stoker is employed in addition to the driver. Aside from attending to the fire, it is his duty to regulate the cut-off when the driver is at the other end of the car, as only brake and throttle connections are provided there.

The motor consists of two single-expansion cylinders, 12 by 16 inches, coupled direct to the rear driving wheels, which in turn are coupled to the front drivers. Walschaert valve gear is used. The water supply is carried in tanks hung beneath the car midway between the trucks. The cars are equipped with brakes. A maximum speed of fifty-five miles per hour can be obtained, although the average running speed is from thirty to thirty-five miles per hour. Their maximum acceleration is about one mile per hour per second.

Taff-Vale Railway.—The Taff-Vale Railway has built a number of cars for its own use and for other railways, being similar in design to the Great Western car, the chief difference being in the construction of the boiler. This is of the fire-tube type and consists practically of two horizontal barrels placed on either side of a central furnace, the hot gases passing horizontally through the fire tubes to the smoke box at the outer ends, and from there through the flues to a central stack. The boiler is placed transversely with reference to the car body and rests directly upon the truck frame back of the forward

axle, which is the driving axle. The forward end of the car body is pivoted on the power truck, but does not include a compartment for boiler equipment, as in the case of the Great Western. The power truck is self-contained and a cab is provided for the driver similar to that of a small locomotive. The cylinders are placed outside and the valves operated by an ordinary link motion with rocking shaft. This car is capable of running thirty-five miles per hour on the level and will ascend a 2½ per cent grade at twenty miles per hour. It can be operated from either end, and all operations, except starting, are performed from the guard's compartment. The following data show the general dimensions of the car and power truck on the latest type of Taff-Vale car:

Over all, length, about 70 feet.
Seating capacity, 43.
Total weight, 42 tons.
Weight on power truck, 30 tons.
Cylinders: bore 10½ inches, stroke 14 inches.
Total heating surface of boiler, 465 square feet.
Grate area, 10 square feet.
Capacity of water tank, 550 gallons.
Steam pressure, 180 pounds.
Tractive force, 5,292 pounds.
Boiler has 232 tubes, 1⅝-inch.

Lancashire & Yorkshire Railway.—The Lancashire & Yorkshire Railway has cars similar to the Taff-Vale, in that the forward end is pivoted on the power truck. The boiler is of the usual locomotive type with horizontal fire tubes. The engine is practically a small locomotive with drivers coupled. The following gives the principal engine and boiler dimensions:

Heating surface:

199 fire tubes, 1¾-inch outside diameter, area	455 sq. ft.
Fire box area	54 sq. ft.
Total	509 sq. ft.
Grate area	9.4 sq. ft.
Water capacity	550 gals.
Boiler pressure	180 lbs.
Coal	1 ton

Two cylinders, bore 12 inches, stroke 16 inches.

Ganz System.—Ganz cars are used rather extensively in Central Europe in three sizes, 35, 50 and 80-horsepower at 260 revolutions per minute. The general arrangement is the same in all three, the boiler being placed in a compartment at the forward end of the car, together with fuel bunker, feed pumps and controlling apparatus. The motor is placed horizontally on the leading truck, and drives the rear axle through spur gears. It is supported in the usual electric railway motor style, one end being swiveled above the axle, and the other supported elastically from the truck frame. The car is controlled from only one end, and one man is required to operate it. The boiler consists of four concentric cylinders with headers (held in place by bolts) forming two annular water spaces joined together by means of slightly inclined steel water tubes, 25 millimeters outside diameter, and 2 millimeters thick. Within the inner cylinder is another cylinder of slightly smaller diameter through which the fuel is fed to the grate below, the flame and hot gases passing around the water tubes to the stack. The motors are two-cylinder cross compound. The largest car, 80 horsepower, weighs 23 tons, and is capable of climbing 1.6 per cent grade, with two trailers weighing 12 tons each, at a speed of twenty-five miles per hour.

Purrey System.—The Paris-Orleans road has ten cars and twelve power trucks equipped with the Purrey System. This system has also been used for a number of years on different tramway lines in the city of Paris.

The Paris-Orleans cars have a total length of about 60 feet, with a capacity of thirty third-class passengers in three compartments, and twenty-five first-class passengers in twenty-two compartments, and in addition there is a baggage compartment at the forward end 11 feet 6 inches long. The forward end is pivoted on the power truck, the rear end being carried upon a single axle. The total weight of this car is about 35 tons. The power truck, which carries the boiler, motor, fuel, water, etc., has a 126-inch wheel base, the rear wheels only being used for driving. The Purrey boiler is tubular, consisting of two drums, the lower one of rectangular section and made of cast steel, the upper one cylindrical and of cast iron. The lower drum is divided into three compartments, two of which are provided for water, the third being for superheated steam. The outer and lower compartment is connected with the upper drum by two large return pipes. It is also connected with the intermediate compartment of the same drum by 41 U-shaped tubes. The feed-water entering the lower compartment is thus heated in passing through these tubes, which are in direct contact with the flame. From this point the water rises through a series of U-shaped tubes to the upper drum, and the steam thus formed is returned from the upper drum through a number of similar tubes to the third compartment of the lower drum, from which it is taken to the motor. The steam is highly superheated in these tubes, the average temperature of superheat being from 750 degrees to 900 degrees F. Coke is used for fuel,

fed automatically from a bunker attached to the side of the boiler, the supply being regulated by a vertical sliding door. The motor is a four-cylinder tandem compound, rated at 260 horsepower at 650 revolutions per minute. Ordinary D-type valves are used, operated through Stephenson link motion. In this design the motor is attached horizontally to the frame of the car and its power transmitted to the rear axle by two toothed chains of similar construction to the Renold and Morse silent type. As a rule, one or two trailers are attached to these cars, the average weight of the train being fifty tons. The fuel consumption of this train is about 21 pounds of coke per mile. The car is capable of maintaining a speed of about fifty-six miles per hour. The cost of operation per train-mile is about seven cents.

Serpollet System.—The Serpollet system differs from the Purrey and Ganz types chiefly in that the boiler is of the flash type, and kerosene is generally used as fuel. A very high degree of superheat is obtained (reaching even 1,200 degrees F.), which, together with the incrustation attending the use of more or less impure water, is conducive to the burning of tubes. The experience of the Paris, Lyons & Mediterranean Ry. with this type of car has been rather unsatisfactory, because of tube troubles, and the Purrey car is now being adopted in its place.

Komarek Car.—This car is used to some extent by the Austrian State Railway and several of its branches. It is manufactured by F. X. Komarek in Vienna. Although built in several sizes and many forms, the following type may be considered as representative:

Car body, total length, 51 feet.

Seating capacity, 35.

Baggage-room, 44 by 96 inches.

Length of boiler and fuel compartment, 10 feet.
Weight, empty, 20 tons.
Coal capacity, 1,100 pounds.
Water capacity, 420 gallons.
Motor, 2-cylinder, cross-compound, outside cylinders.
Cylinders, diameter, 10 by 15 inches, stroke 16 inches.

This car is capable of running at a speed of twenty-five miles per hour on a level while hauling trailers comprising a total of 50 tons. The operating cost is said to be about five cents per train-mile (exclusive of the guard's pay), coal costing $3.25 per ton, made up as follows:

Coal	$0.0253
Oil	.0014
Labor	.0046
Maintenance:	
Material	.0011
Driver	.016
	$0.0484

CONCLUSION.

That there is a field for the rail motor car can not be questioned; its breadth at the present period being limited only by the development of the motor-car power equipment.

Steam, as a motive power, has always possessed the distinct advantage of flexibility of control as well as reliability.

The internal combustion motor within certain defined limits of horsepower sizes has been developed to that stage of excellence where these advantages can not be said to apply exclusively to the steam engine.

With the experimental work that is being conducted in the development of the internal combustion motor using lower cost fuels than gasoline, and with promising results, who can predict the final outcome of the motive power that will be the most satisfactory from all points of view for the rail motor car? It is probable that both types will have their distinctive fields, depending upon the availability of the fuel.

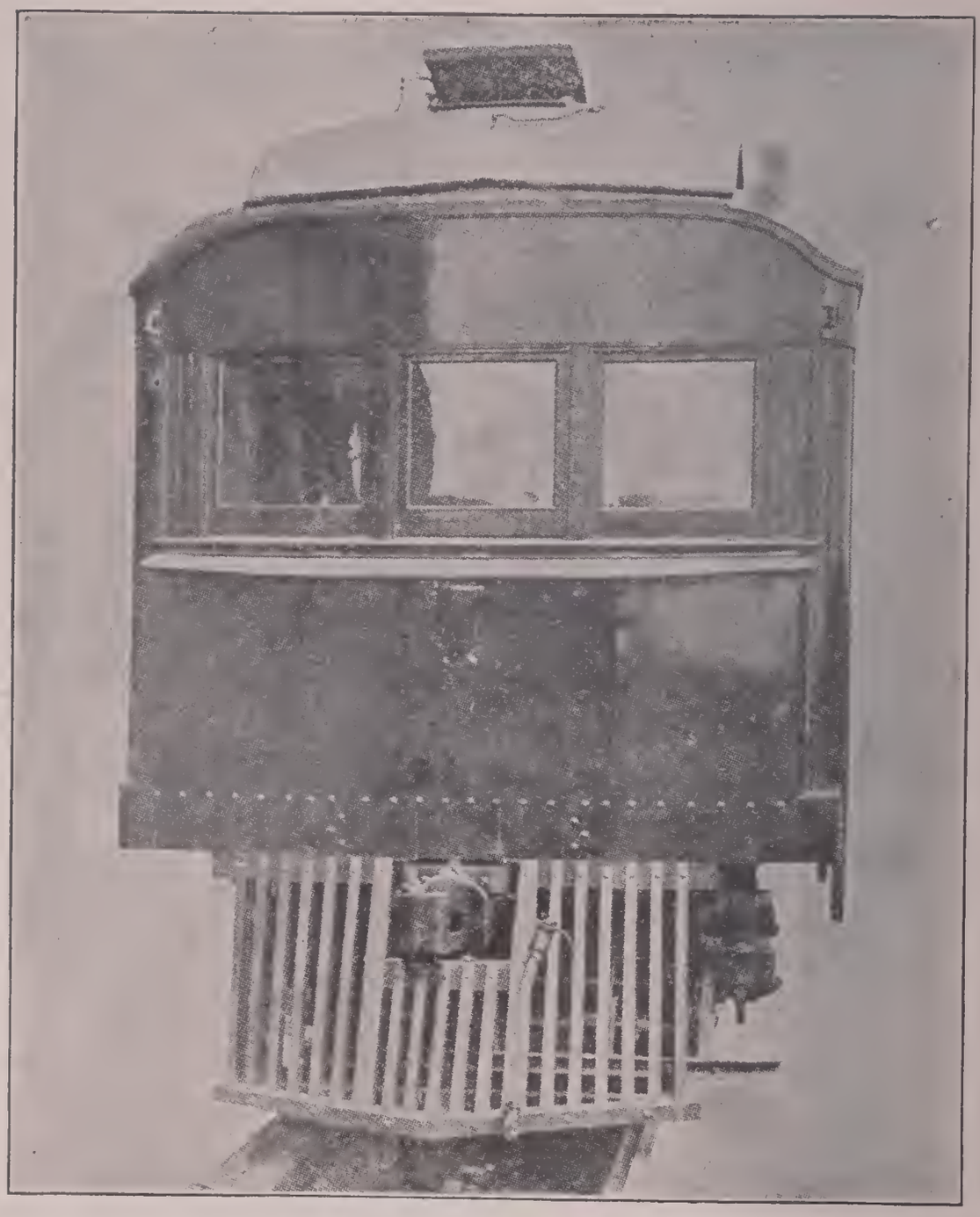
GANZ STEAM MOTOR CAR.

The first car of this type to be constructed in this country was built for the Erie Railroad at Dayton, O., by the Railway Auto Car Company of New York, which controls the Ganz patents on this continent.

In brief, the car consists of two compound enclosed steam motors of 60 h.p. each, which are mounted on the forward truck and drive the axles through gearing. In the forward end of the car above the truck is a steam generator which furnishes superheated steam at 270 lbs. pressure for the motors.

The car body is of wooden construction and in exterior appearance is very similar to a composite passenger and baggage suburban car. It measures 58 feet over all and seats 50 passengers. The compartment at the forward end is 6 feet long and contains the steam generator with its accompanying pumps and also the control apparatus for the motors, engineer's brake valve, etc. The fuel, which is either anthracite coal or coke, is carried in a bunker in the forward end of the car projecting out beyond the car body and arranged to be filled from the outside. This bunker will hold enough coal for a continuous run of 50 miles. Just back of the generator room is a 6 foot compartment for baggage, behind which is a smoking compartment to seat 12 passengers. The remainder of the car is a general passenger compartment. This car weighs 45 tons in working order.

The steam motors have cylinders 4.7 and 6.7 x 5.5 in. and are arranged so that either can be operated indepen-



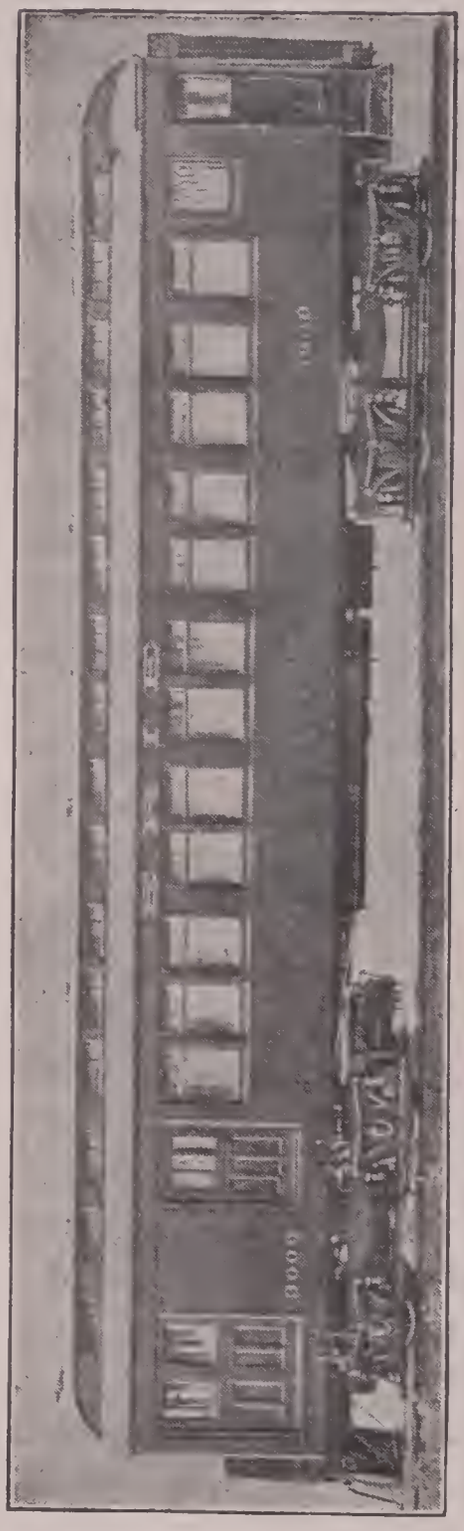
View of Ganz Motor Car Showing Coal Bunker.

dently or both work together. The maximum tractive effort is 3,700 pounds. They are completely enclosed in dust-proof cases, which are partially filled with oil so that all moving parts receive continuous and thorough

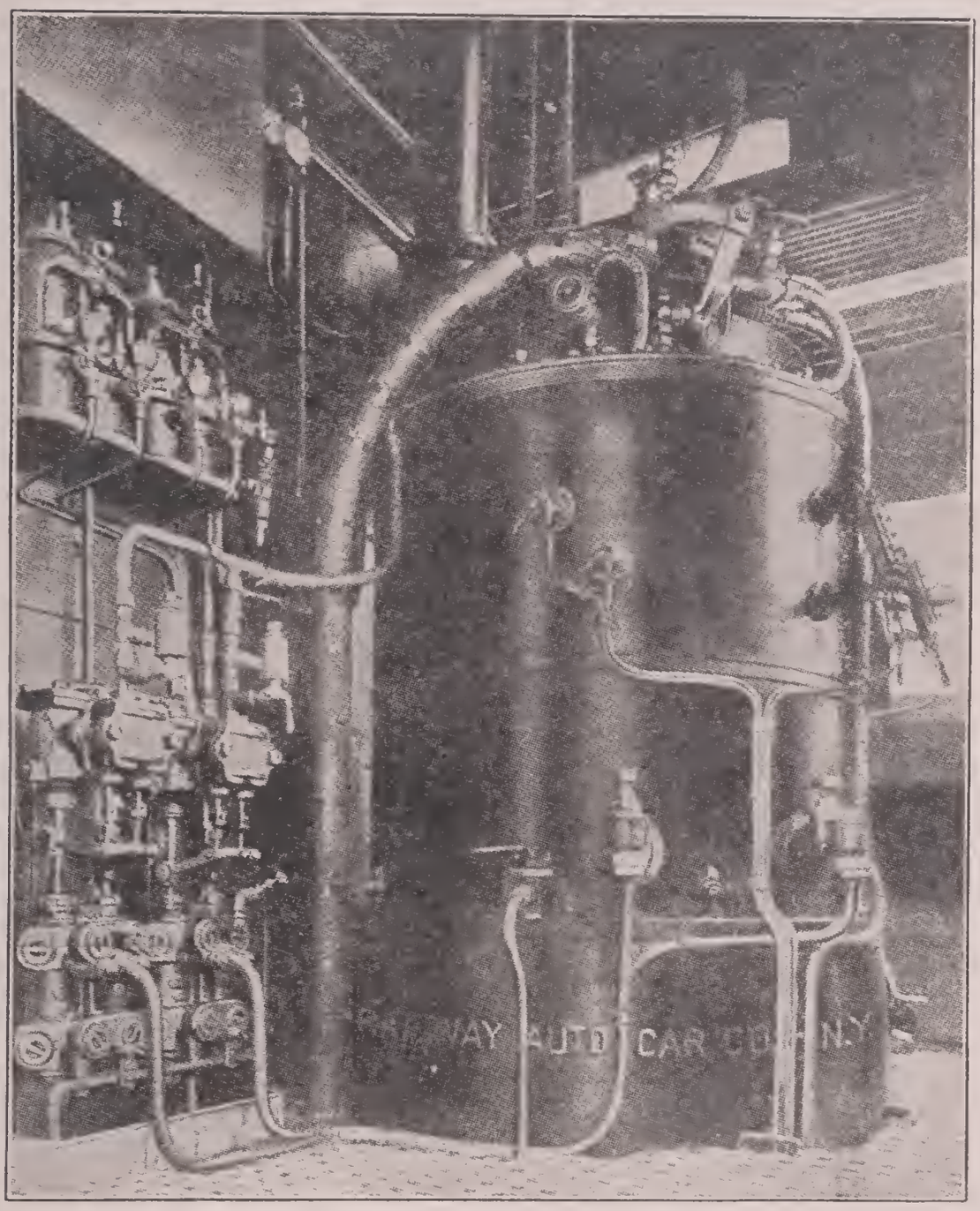
lubrication. The cylinders are steam jacketed and the motors are to be operated at a normal speed of 600 revolutions per minute, although they will run satisfactorily up to 900 revolutions per minute. A by-pass valve is provided for admitting high pressure steam to the low pressure cylinder to increase the tractive effort at starting or when otherwise necessary. The motors are hung from the frame of the truck by spring suspension, the steam connections to the generator being flexible. Universal joints are fitted to all of the operating rods for controlling the motors. There is an intermediate shaft interposed between the crank shaft and the driving axle which carries three gears, one being in permanent engagement with the gear wheel on the axle, and the other two being fitted with friction clutches. These are of different diameters and can be thrown in one at a time, one combination giving full gear and the other half gear speed.

One of the illustrations shows the all steel truck which carries these generators. This truck is specially designed for this purpose and is practically identical with the trucks used on the Ganz cars abroad.

The steam generator is 42 in. in diameter and 5 ft. high. It is of the water tube non-explosive type and consists essentially of four steel cylinders arranged concentrically. The spaces between the two outer cylinders and the two inner ones form the water legs of the boiler and these two spaces are connected by a large number of small tubes which constitute the bulk of the heating surface of the boiler. The water level is below the upper tubes and hence these act as a superheater. The total amount of water in the boiler is comparatively small and a continuous feed is provided from the pumps. This boiler has a heating surface of 212 square feet and a



120 Horse Power Ganz Steam Motor Car.



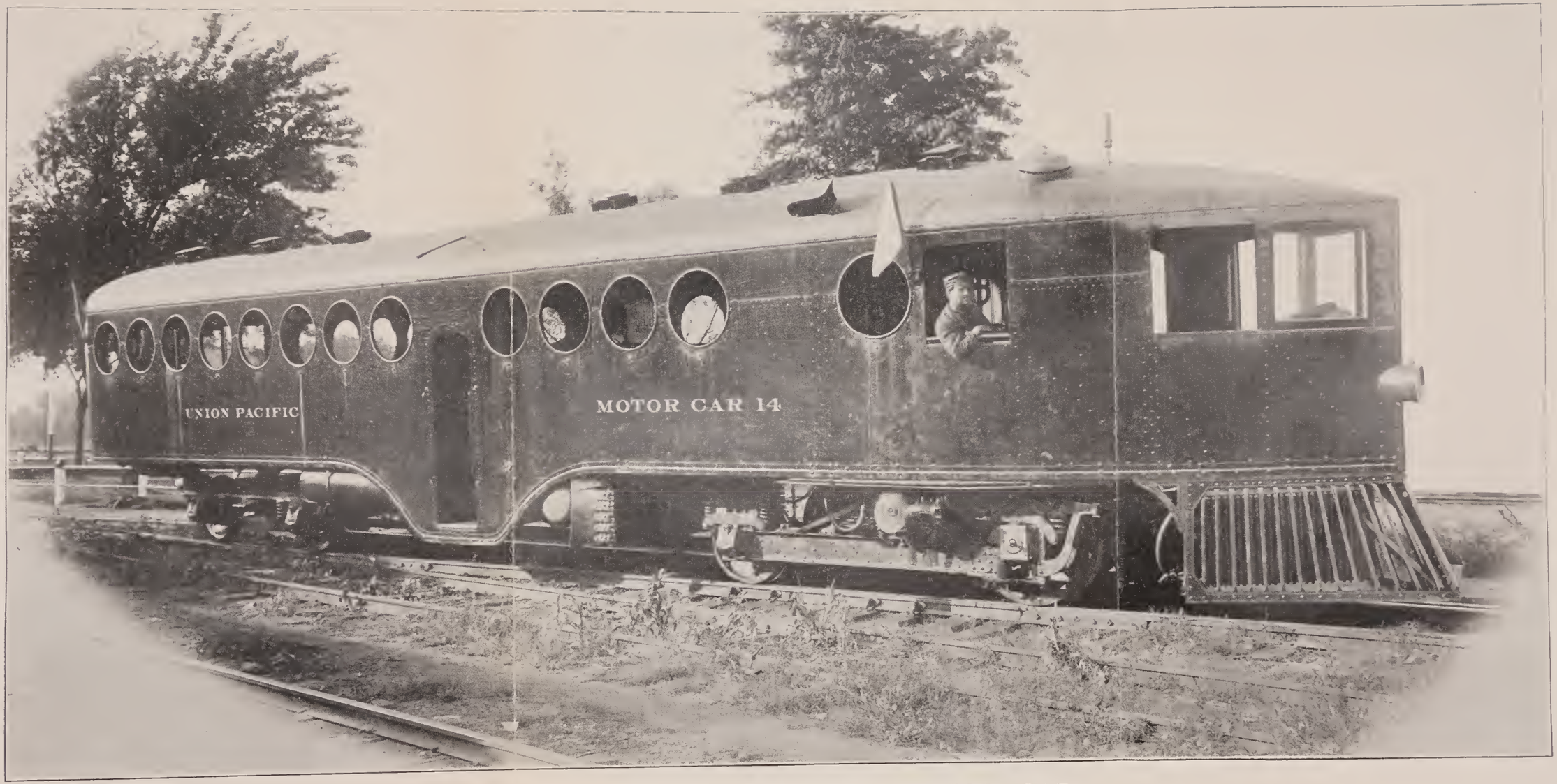
Steam Generator—Ganz Motor Car.

grate area of 6 square feet. It is rated at 120 horse-power, delivering the superheated steam at 270 pounds pressure. It is claimed that steam at this pressure can be obtained in from 20 to 30 minutes from cold water, using either coke or anthracite coal.

Provision has been made for easily exposing the tubes for cleaning and the boiler is provided with a patented construction at the mouth of the feed pipe by means of which the feed water assists in cleaning out any mud that clings to the tubes. The water supply is carried in a tank of 600 gallons capacity built in the underframe of the car.

The air brakes are of the Westinghouse type, the air compressor being mounted on the trailer truck and driven from one of the axles of the truck. Lighting is by commercial acetylene gas and the car is heated by steam.

This car is designed for a speed of 40 miles per hour on the level and 15 miles an hour on two per cent grades and will haul a trailer at a speed of 30 miles per hour on a level track.

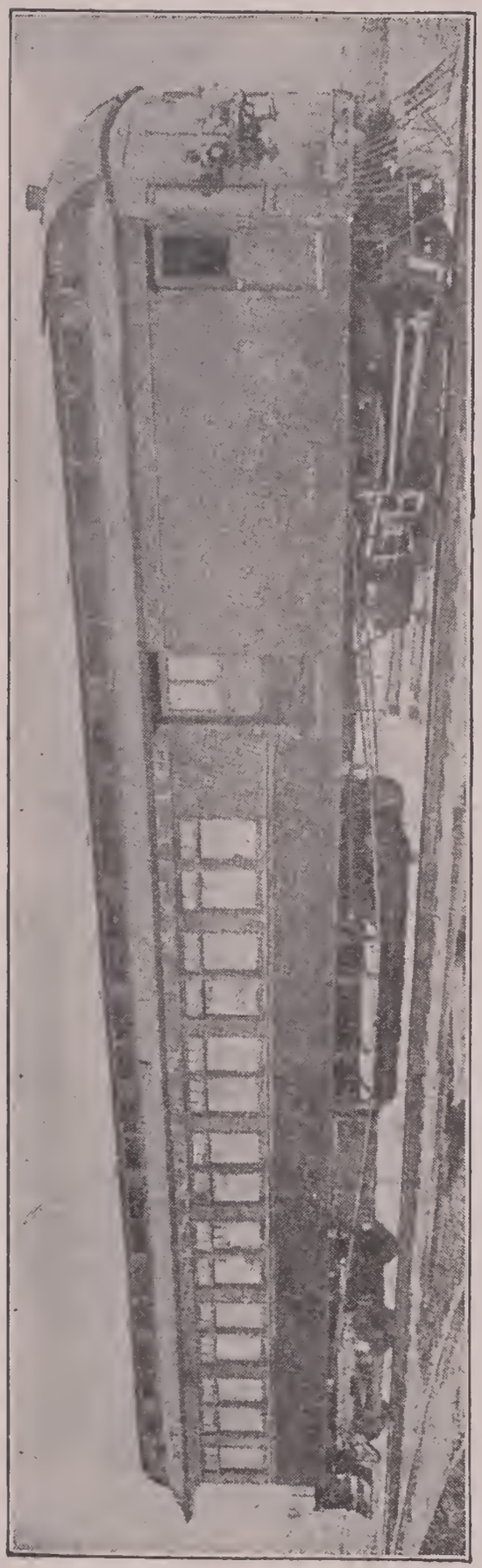


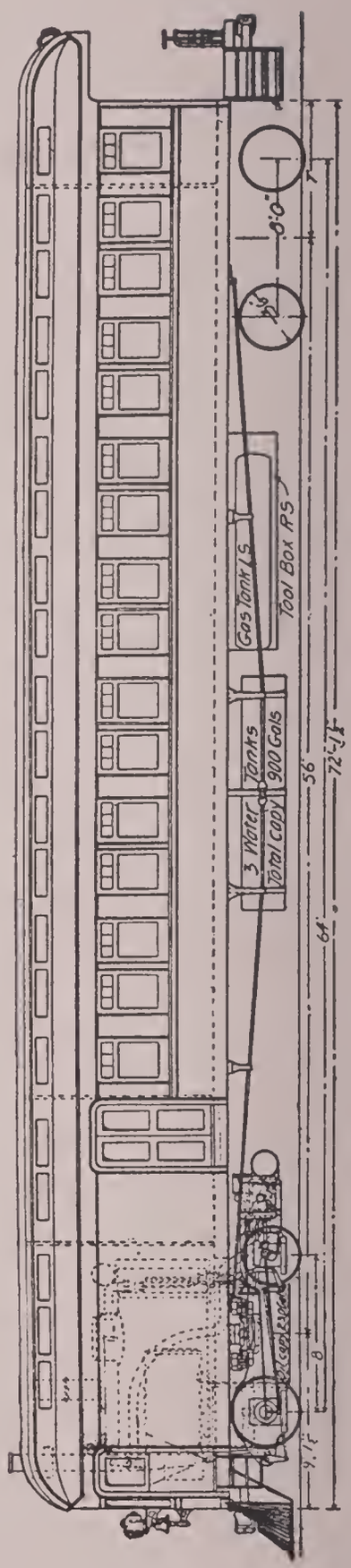
UNION PACIFIC GASOLINE MOTOR CAR

STEAM MOTOR CAR.

The general appearance of this car is shown in our illustrations. It was built for the Rock Island System. It is a 250 horsepower compound steam motor car. The car body is of steel throughout, with the exception of the interior finish. It is divided into three compartments, an engine room, baggage room and passenger compartment, having a seating capacity for 40 passengers. This last compartment also includes toilet facilities. The car is 55 feet 9 inches long over platforms, and weighs in working order 100,000 pounds. Of this weight 38,300 pounds is carried on the trailing truck and 61,700 pounds is on the motor truck, of which 32,400 pounds is on driving wheels. It has shown its capacity for high speed, having on several runs made speeds of 60 miles an hour.

In the design of the car body the aim was to make it as light as possible consistent with great strength. With this object in view, therefore, the truss rod construction was employed instead of following the more usual practice in the construction of steel cars of making the side frames below the window plate in the form of a girder or truss of sufficient strength to carry the whole weight of the car. The side posts are rolled steel angles riveted at the bottom to the side sills, and at the top to the side plate angles, which extend in one continuous piece the entire length of the car, on each side, and are bent at ends to the shape of the end of the car. The carlines are steel channels, bent to conform to the contour of the roof, which is of the round type.



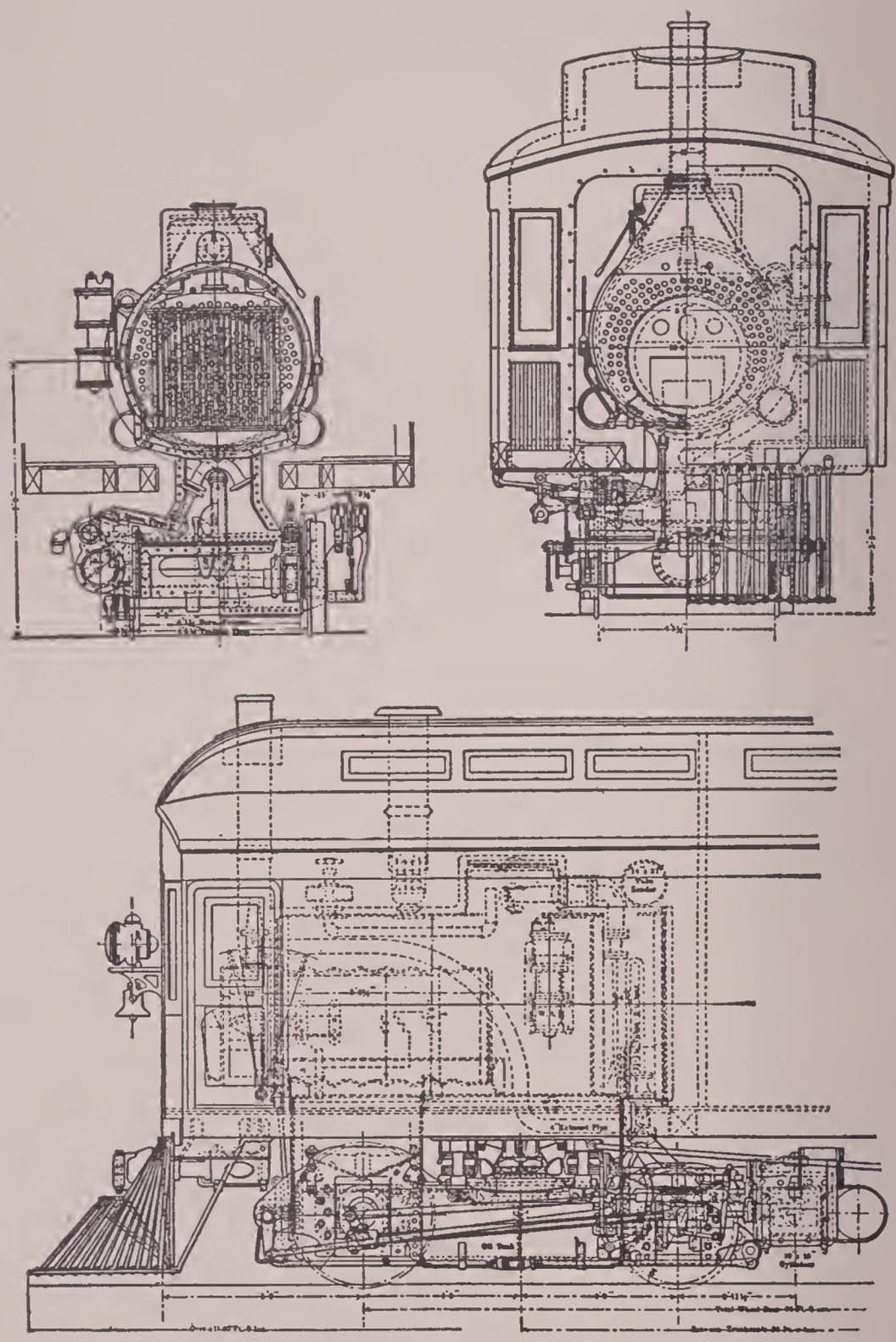


Steam Motor Car, Canadian Pacific Railway—Side Elevation.

The side sills consist of 6x4x1½-inch steel angles reinforced by 1½-inch truss rods and the center sills are 8-inch I-beams. For a distance of 30 feet back from the front end, the side sills are reinforced by 6x4x½-inch angles riveted to the sills in such a manner that the horizontal leg is uppermost furnishing a bearing surface for the floor of the engine room. The end sills are 8-inch steel channels securely fastened to the side sills by means of wrought iron corner plates and to the center sills by angle connections. A number of steel angles, fastened to the side sills and center sills by angle connections tie the center and side sills together between the bolsters. These cross braces also serve as supports for the floor.

The bolster at the trailer end of the car is of the built-up type, while that at the motor end is of cast steel, made in three sections so that the middle section may be readily removed to permit of the boiler and engine being drawn out from the end of the car. The middle section of the front end framing of the car body and the flooring ahead of the engine are also made removable for this same purpose.

The floors of the passenger and baggage compartments consist of two layers of wood, the upper layer being laid diagonally across the car, while the floor of the engine room is of steel with wood covering; the section ahead of the engine between the center sills, being as before mentioned, removable. The inside sheathing of the passenger and baggage compartments is of mahogany and the head lining is fire-proofed board. Light is provided by five pairs of oil lamps hung from the center of the car, there being four pairs in the passenger compartment and one in the baggage room.



Steam Motor Car, Canadian Pacific Railway—Engine Room and Motor Truck.

The car is equipped with spring buffer and M. C. B. single spring draft rigging.

In the design of the boiler the problem of providing the required amount of heating surface within the necessarily limited space available has been very satisfactorily solved. The boiler is of the horizontal return tube type. The fire box and smoke box are at the front end and the gases of combustion pass through the few tubes to an intermediate smoke box chamber at the back end, and thence forward through the return tubes to the smoke box. The barrel of the boiler, which is in one sheet 61⅜ inches long, measures 49 inches diameter inside at the fire box end and 44 inches in diameter inside at the intermediate smoke box end. It contains 214 fire tubes 1¼ inches in diameter, and 3 feet 9 inches long and an equal number of return tubes of the same diameter, but 3 feet 11½ inches long. The total heating surface of the boiler is 624.4 square feet, which gives 2.5 square feet per horsepower. Of this heating surface, 527.8 square feet is in the tubes and 37.6 square feet in the fire box and the remainder in the superheater.

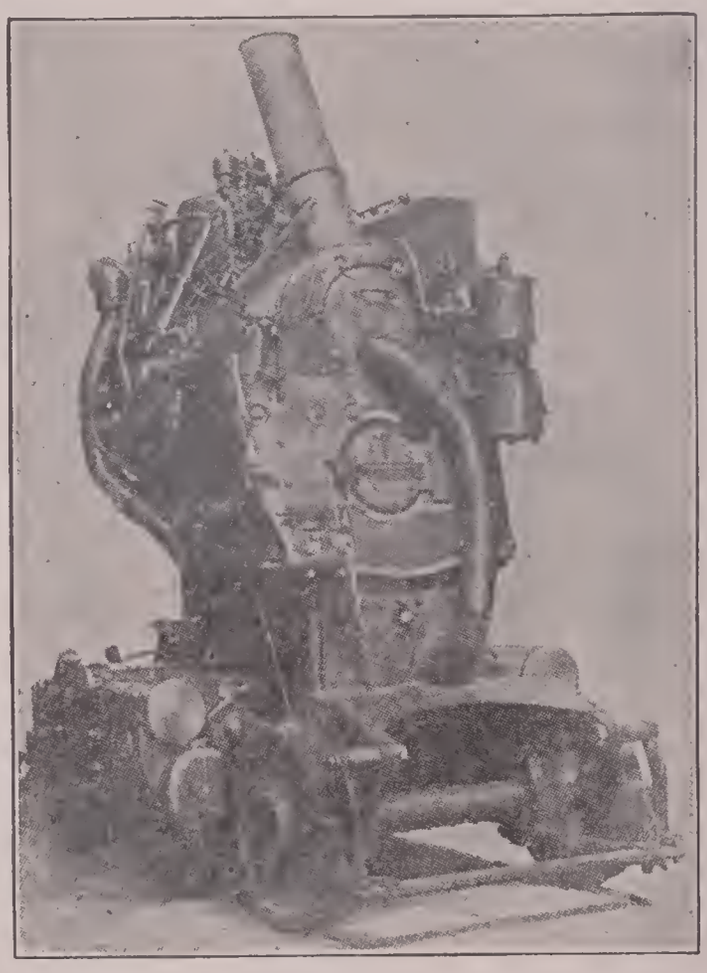
The fire box is 33⅛ inches long and 43¼ inches wide and is bricked for burning oil. The oil burner, which is in the fire door, is of special design and is provided with a fan shaped deflector which directs the oil downward toward the hot fire bricks and also spreads it out over the fire box, thereby tending to produce better combustion. The superheater is of the smoke box type and is in the intermediate smoke box chamber where the temperature of the gases is high. The superheater tee-head is bolted to a cast steel box saddle casting which in turn is bolted to the top of the boiler, and covers the opening cut through the sheet by which the superheater tubes extend

Steam Motor Car, Chicago, Rock Island & Pacific.

down into the smoke box chamber. The tee-head is divided transversely into a front and a rear compartment by means of a vertical partition. There are sixteen superheater tubes bent into the shape of a double loop, one end of each loop being connected with the front or saturated steam compartment, and the other end with the rear or superheated steam compartment. Steam flows from the dome through a short dry pipe into the saturated steam compartment; and thence through the superheater loops into the superheated steam compartment, and from thence into the steam pipe to the high pressure steam chest. The boiler is rigidly connected to the motor truck frames, so as to eliminate the necessity of flexible steam joints. The engine is of the two cylinder cross compound type, the high pressure cylinder being 9¼ inches in diameter by 12 inches in stroke, and the low pressure cylinder, 14½ inches in diameter, by the same stroke. The Mellin system of compounding is used, the intercepting valve being in the high pressure cylinder casting. Both cylinders are equipped with piston valves actuated by the Walschaert valve gear. The cylinders are in separate castings and are rigidly bolted to the side frames of the motor trucks. They drive on the rear wheels of the truck, which are 38 inches in diameter. With a boiler pressure of 250 pounds the engine will develop a theoretical maximum tractive effort, working compound, of 4,300 pounds.

The motor truck is of the four wheel swinging bolster type. The side frames, which are of cast steel, are 3½ inches wide, and are rigidly tied together by the cast steel transoms and by cross ties suitably placed. The bolster is carried on double elliptic springs. The weight on the rear or driving journals is carried by a semi-elliptic

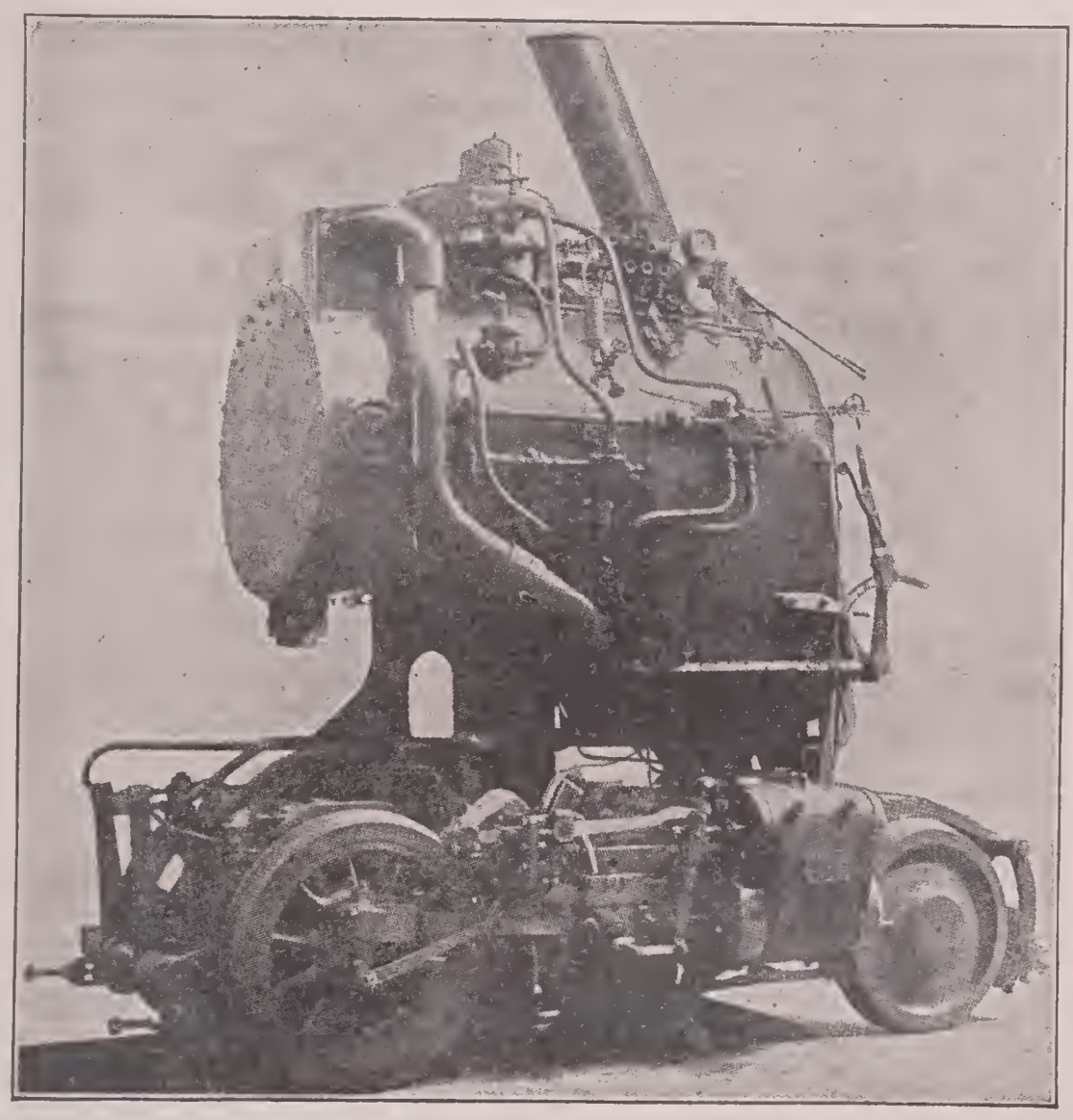
spring, suspended between two cross equalizers whose ends rest on top of the journal boxes, while the weight on the forward journals is carried by coil springs, one on top of each journal, thus giving a three-point suspended truck. The trailer truck is of the four wheel, two bar



End View of Boiler and Engine.

equalizer type, with solid wrought iron top frame, swinging bolsters of the built up type, channel iron transoms and cast steel transom gussets. The wheels are 34 inches in diameter and the journals are 4¼x8 inches. Both motor and trailer trucks are equipped with New York Air Brake Co.'s air brakes operated by an 8-inch Westinghouse pump. New York air signal equipment and Gold

steam heating equipment is also provided. The oil for fuel is carried in a tank in the engine room and having a capacity of 100 gallons. The water supply is in three tanks, having a total capacity of 1,000 gallons, suspended beneath the car midway between the trucks.



The Motive Power of the Car.

The principal dimensions of the car are as follows:

Total weight, 100,000 lbs.; weight on leading truck, 61,700 lbs.; weight on drivers, 32,400 lbs.; weight on

leading wheels, 29,300 lbs.; weight on rear truck, 38,300 lbs.

Total wheel base, 45 ft. 10 in.; distance between truck centers, 38 ft. 3 in.; wheel base of driving truck, 8 ft. 4 in.; length of car body over sheathing, 52 ft.; length of car body over platform, 55 ft. 9 in.

Diameter of Cylinders.—High pressure, 9¼ in.; low pressure, 14½ in.; stroke, 12 in.; valves, piston; valve gear, Walschaert.

Wheels.—Driving, diameter, 38 in.; leading, diameter, 33 in.; rear truck, diameter, 34 ins.; journals, driving, 6x12 in.; journals, trailing truck, 4¼x8 in.

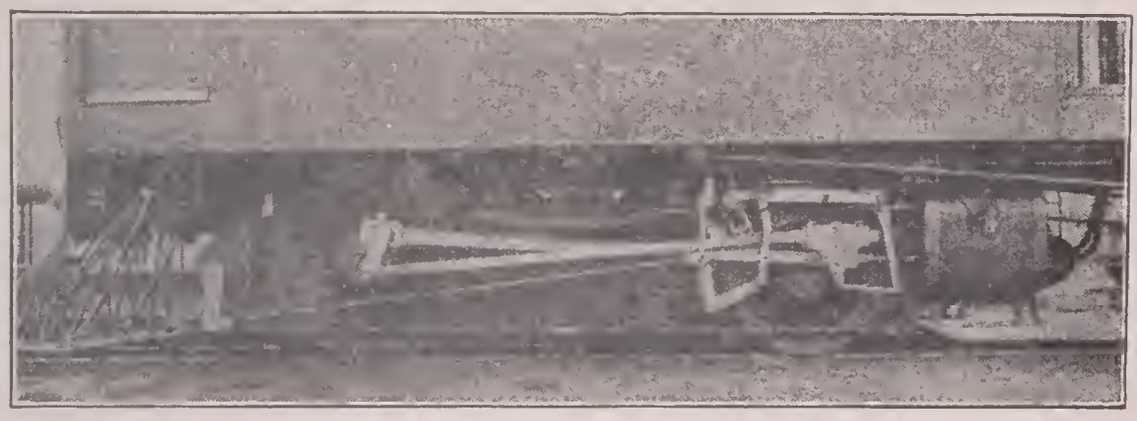
Boiler.—Outside diameter at intermediate smoke box end, 444 ins.; fire box, length, 33⅛ in.; fire box, width, 43¼ in.; tubes, diameter, 1¼ in.; tubes, number and length, 214, 3 ft. 9 in.; 214, 3 ft. 11½ in.; heating surface, tubes, 527.8 sq. ft.; heating surface, fire box, 37.6 sq. ft.; heating surface, superheater, 59 sq. ft.; heating surface, total, 624.4 sq. ft.

STEAM MOTOR CAR, CANADIAN PACIFIC RAILWAY.

The accompanying illustrations are of a steam motor car operated by the Canadian Pacific Railway which makes four round trips a day. It was designed by Mr. H. H. Vaughan, assistant to the vice-president, and built under his direction. It is one of the largest motor cars in America. The length of the car is 75 feet, and is divided into engine room, baggage and express, smoking and first-class compartments, the smoking compartment seating 16 and the first-class compartment seating 40

passengers. The following data concerning it will be of interest:

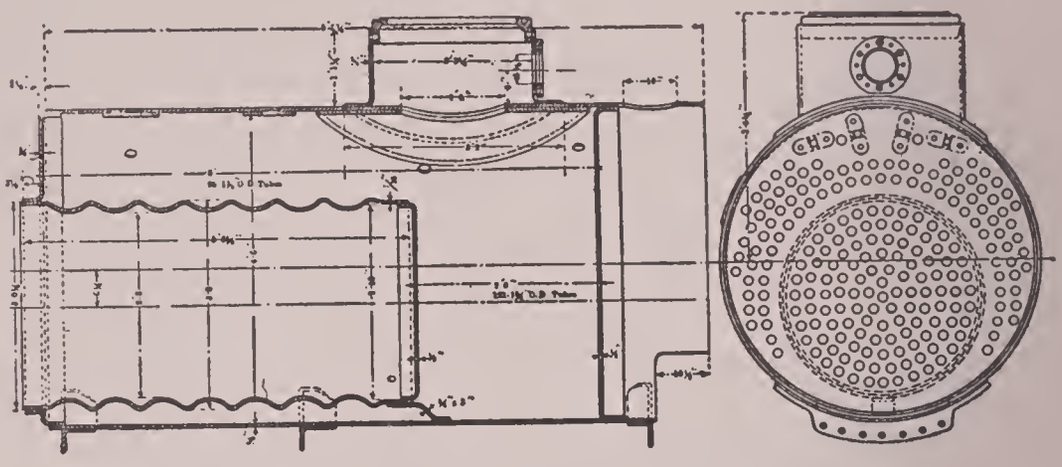
The boiler is of the return tube type, being 4½ feet inside diameter by 7 feet 11 inches between flue sheets, and contains one 33-inch corrugated furnace and 95 1¾-inch tubes, and has a total heating surface of 536 square feet, of which 485 are in the tubes and 61 in the furnace. The superheater consists of 31 1¼-inch steel tubes, and contains 62 square feet of superheating surface. Pistons are of cast iron 10 inches in diameter by 3 inches thick. Cylinders 10x35 inches have inside ad-



Steam Motor Car, Canadian Pacific Railway—Side View of Motor Truck.

mission piston valves which are operated by valve gear. Driving and trailing wheels have centers made of cast steel, the former being 42 inches on tread, the latter 34 inches on tread. All journals under motor are 8x12 inches and under truck of car 5x9 inches. Main frames of motor are made of ⅞-inch steel plate. The total weight of car in running order is 136,620 pounds, of which 82,880 are at the motor end of car and 53,740 at the rear end of car, the portion at the motor end being divided—42,440 pounds resting upon the driving wheels and 40,440 on the trailing wheels. The fuel used is crude oil, and is carried in a tank having a capacity of

2,000 pounds, which is built in frame of motor and is being under a constant air pressure of 15 pounds per square inch. The oil is fed to furnace by a slot burner, and the supply cock and blower are controlled by an automatic device. The car is provided with water tanks having a total capacity of 900 imperial gallons, these being fastened to the underside of car body, and the water is fed to boiler by one No. 3 and one No. 5 in-



Steam Motor Car, Canadian Pacific Railway—Boiler.

jector. The steam working pressure is 180 pounds, and it is superheated so that upon reaching the valve chest it has a temperature of from 700 to 760 degrees Fah. The corrugated flue in boiler is lined with fire brick, and the boiler is also equipped with sand-blowing device for cleaning soot off the tubes. The car is equipped with Westinghouse Co.'s A. M. T. automatic system, which has a graduated release and is especially adapted for this class of service.

The car with the motor equipment weighs from 90,000 to 92,000 pounds; it is a four-wheeled truck car. The water carried adds 9,000 pounds to that and the motor 30,000 pounds, making the total weight of the car about

INTERIOR OF UNION PACIFIC GASOLINE MOTOR CAR

130,000 pounds. Boiler is the modified Scotch boiler, with a superheater and combustion chamber, or intermediate chamber, and circular furnace. One interesting feature is that on this small car with about a 200 horsepower engine the results obtained in locomotive practice on large boilers and large engines can be duplicated in every respect. The inches of draft per pound of back pressure are duplicated. The evaporation per square foot of heating surface is duplicated. The horsepower the car will develop is practically the same; the weight of the boiler per square foot of heating surface is rather less than in the ordinary locomotive. So a reduced locomotive in every way running on car. The experience shows that it is perfectly safe to apply existing locomotive data to very small cars of that kind and expect the results to be duplicated. The master mechanics' improved form of stack can not be duplicated, however. The stack has to be a little larger than the formula gives. I suppose that is because the size of the front end would be 24 inches, and there is not enough room for the gases in the size the formula gives.

After a certain amount of experimenting we put the car in service, and the only troubles we have had are: The first trip the car broke a spring hanger, and the second time a crosshead arm actuating the valve gear. This was due to defective design, but otherwise the car runs satisfactorily. It is making four round trips a day, 23 miles each way. The regular local passenger schedule, 23 miles, is 50 minutes, made in 38 minutes with the motor car. There is no difficulty in running at a speed of 50 to 55 miles to the hour.

The Union Pacific has developed a gasoline motor car suitable for high-speed branch line and interurban

service. The design of the car presents some new features, being modeled after the lines of the racing yacht Reliance, inverted. The rear of the car is rounded off to avoid the formation of the vacuum present with square-ended cars. The front tapers to a sharp point. The roof is given a taper from the middle to produce a splitting effect in the atmosphere and minimize resistance. It is entirely smooth except for the Cottier ventilators, which exhaust by suction the air from the interior of the car.

The truck is of original and unique design with many new features. It is intended to embody the good points of the street car, Pullman and locomotive trucks. The most important feature is the design of the springs. They are so constructed and applied as to avoid the teetering action ordinarily experienced in the old-style trolley car. The truck wheels are 42 inches.

The car is driven by a six-cylinder gasoline engine made by the Standard Motor Works, Jersey City, N. J. It is a remarkable machine and is quite similar to the design used in the Standard auto-boats which made such a wonderful record in the auto-boat races on the Hudson River. The Standard boat No. 1 was capable of a speed of 25 to 30 miles per hour. The engine was re-designed and built in accordance with the railroad company's plans to make it suitable for motor car service. Large air reservoirs are carried underneath the car, and by means of the air passage and a starting device the car is rapidly put in motion and picked up by the engine, attaining a maximum speed, without jar, in a minimum space of time. The designers claim that there is practically no limit to the speed that the car may attain, though it will probably be limited to a service speed of 40 miles per

hour. The clutches and controlling devices are all mechanical and of simple design. Special effort was made to avoid the complicated machinery usually found in gasoline-engine propelled motor boats and cars.

The ventilation of the car is said to be particularly good, the air being almost as fresh as that outside. The air is taken in at the top of the car and by small ducts is gradually diffused throughout the interior. In the winter time the air is passed over hot pipes before entering the car. The impure air is sucked out at the top through the ventilators. Another feature of note in the design is the provision for thoroughly cleaning and disinfecting its interior. The floor is made water-tight so that the car can be flushed out with hot water to kill all germs and sources of infection. The seats are leather and the walls and ceiling are made as smooth as possible to enable thorough cleaning with little labor.

A system of coils through which the water from the cylinder jackets may be circulated, runs around inside of the car for warming it in winter, sufficient heat being radiated to produce a comfortable temperature. Another system of coils is provided under the car for use in summer time. The heating of the car is regulated by a controlling valve which passes more or less water through each system of the coils as the temperature requirements of the interior make it necessary. By means of an air cylinder the rear door is kept closed while the car is in motion. When it is desired to let passengers on or off, the door is opened and the step trap-door lifted by air cylinders operated from the front end. Thus, passengers can not alight from or board the car while it is in motion. The car is considered to be an unusually strong design,

impossible to telescope or crush, affording safety to its passengers in case of collision or wreck.

The lighting is by acetylene, including the headlight. The interior lighting is through opalescent panels, giving a good strong light over the shoulder for reading, while the general lighting is pleasing and restful to the eye. The car is painted maroon, with aluminum trimmings, and it has a seating capacity of twenty-five.

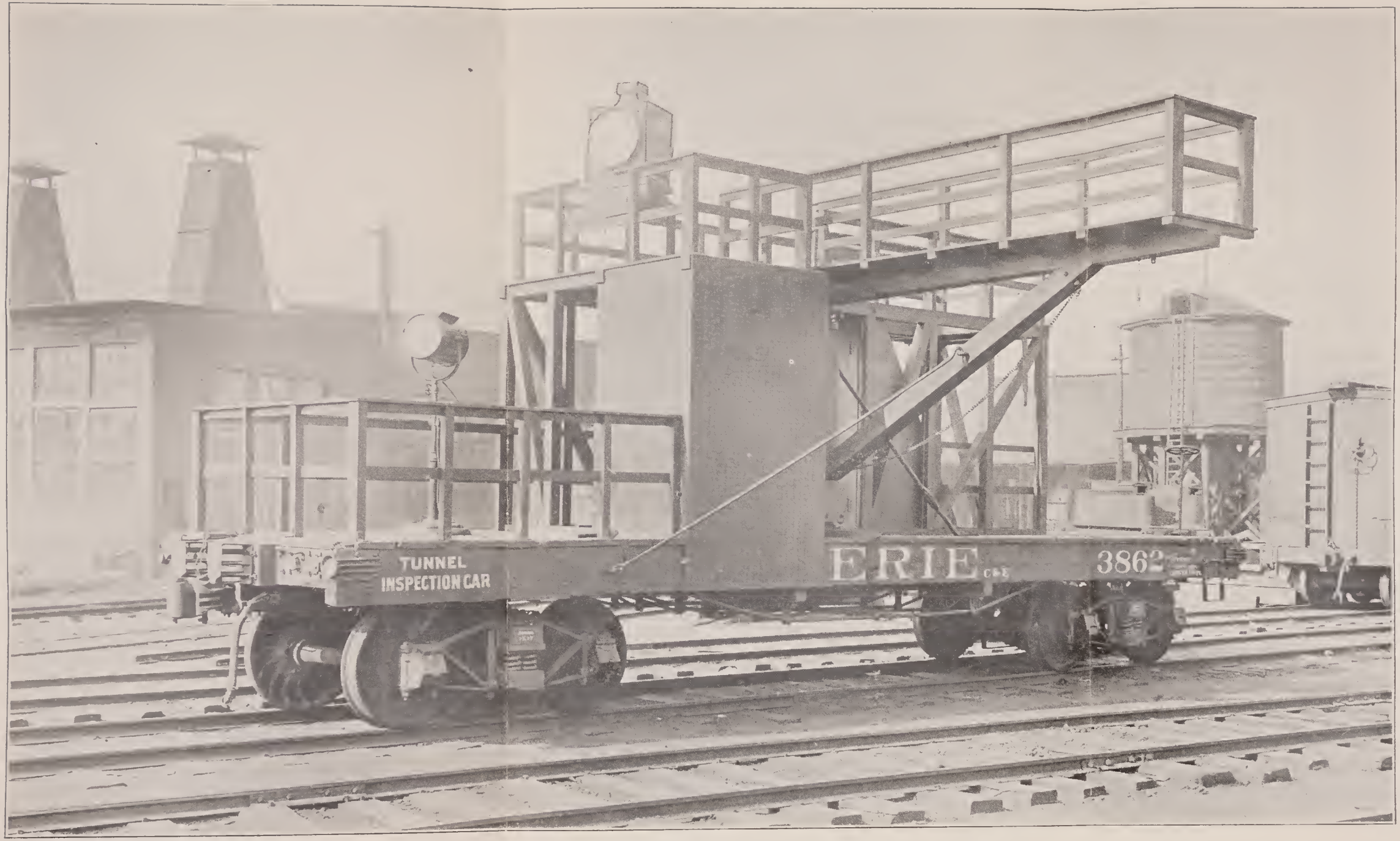
GASOLINE MOTOR CAR—UNION PACIFIC.

This type of car seems to have more than fulfilled all the expected requirements. So eminently satisfactory were the results of the severest sort of tests and trials in service that a company was especially organized to construct them. The accompanying illustrations show the exterior and interior of one of these motor cars of which many will undoubtedly be in service on western roads in the not very distant future.

TUNNEL INSPECTION CAR—ERIE.

This car is a recent development and an entirely new departure in railway car building. The illustration conveys a good idea of its construction and adaptability to the purposes for which it is designed.

The car is fitted with a raised platform and a swinging gangway which can be opened for the inspection of tun-



ERIE R. R. TUNNEL INSPECTION CAR

nel roofs. When the extension is not in use it may be swung up snugly to the platform and there locked. To swing the platform and gangway into position for inspection purposes or to return it to the closed position an extension shaft and set screws are attached to the car floor at the front. On the raised platform there is a standard locomotive headlight, which is so mounted that it may be turned in any direction. The searchlight and also the headlight have acetylene gas burners and by means of fixed piping and flexible connections the gas is obtained from two acetylene storage tanks, each with a capacity of 600 cubic feet. These two tanks are carried under the elevated or raised platform of the car. One tank serves as an auxiliary reserve supply, the other for use.

This car is the outcome of a demand for some quick and easy way of making close and frequent inspection of the "Tube Roofs" of the tunnels under the river between New Jersey and New York City. It has proved so successful that it is likely similar cars will be used for railway tunnel inspection generally, more particularly where blasting has been done.

RACK RAIL LOCOMOTIVE USED ON THE MANITOU AND PIKE'S PEAK RAILWAY.

The rack rail locomotive built by the Baldwin Locomotive Works for the Manitou and Pike's Peak Railway is illustrated by the two cuts shown. This locomotive is provided with three driving pinions, which receive their motion through rocking levers whose fulcrums are bolted

to the engine frame. The Good type of valve motion is used, being indirect, and the reversing is accomplished by a screw mechanism. The engine is compound, being of the Vauclain system. The maximum grade of the road is 25 per cent. In the construction of this locomotive the boiler is so set that its axis, when standing on a 16 per cent grade, is horizontal, while the inclination of the cylinders is 4 in 25.

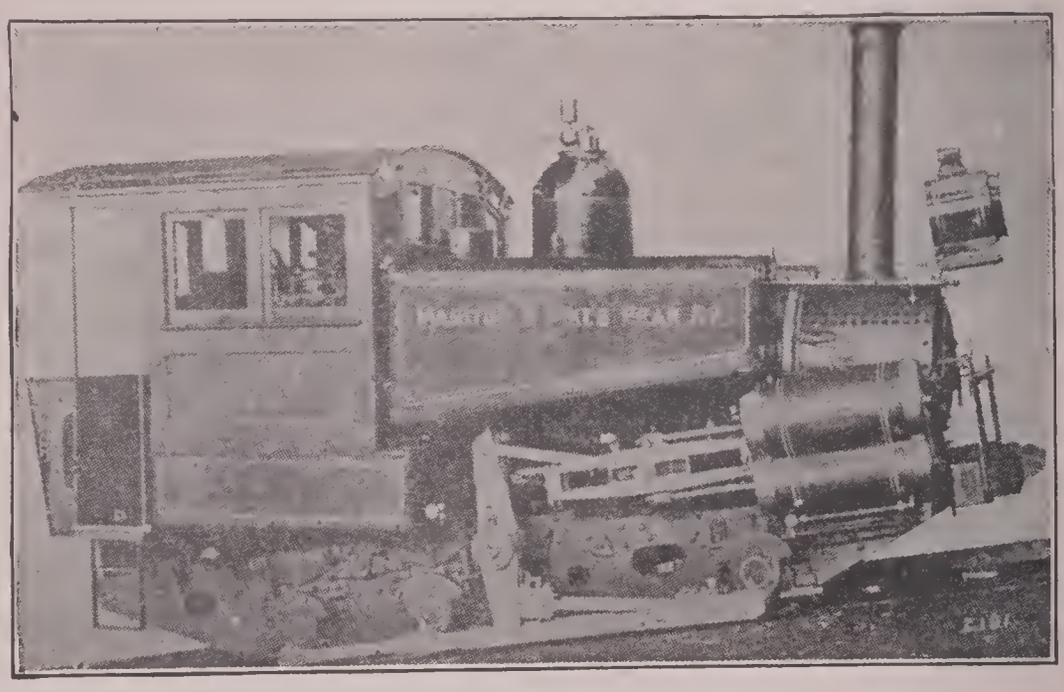


Fig. 1. Rack Rail Locomotive for the Manitou and Pike's Peak Railway.

The fuel used is oil, which is carried in tanks placed on the right and left sides underneath the floor of the cab. Side tanks supported on brackets which are bolted to the boiler shell carry the water supply. Steam, hand and water brakes are provided. A shut-off valve, fitted to the exhaust nozzle, may be operated from the cab, and is for the purpose of preventing air being drawn in from the smoke-box when engine is reversed. The principal dimensions are as follows: Cylinders, 10 and 15 inches

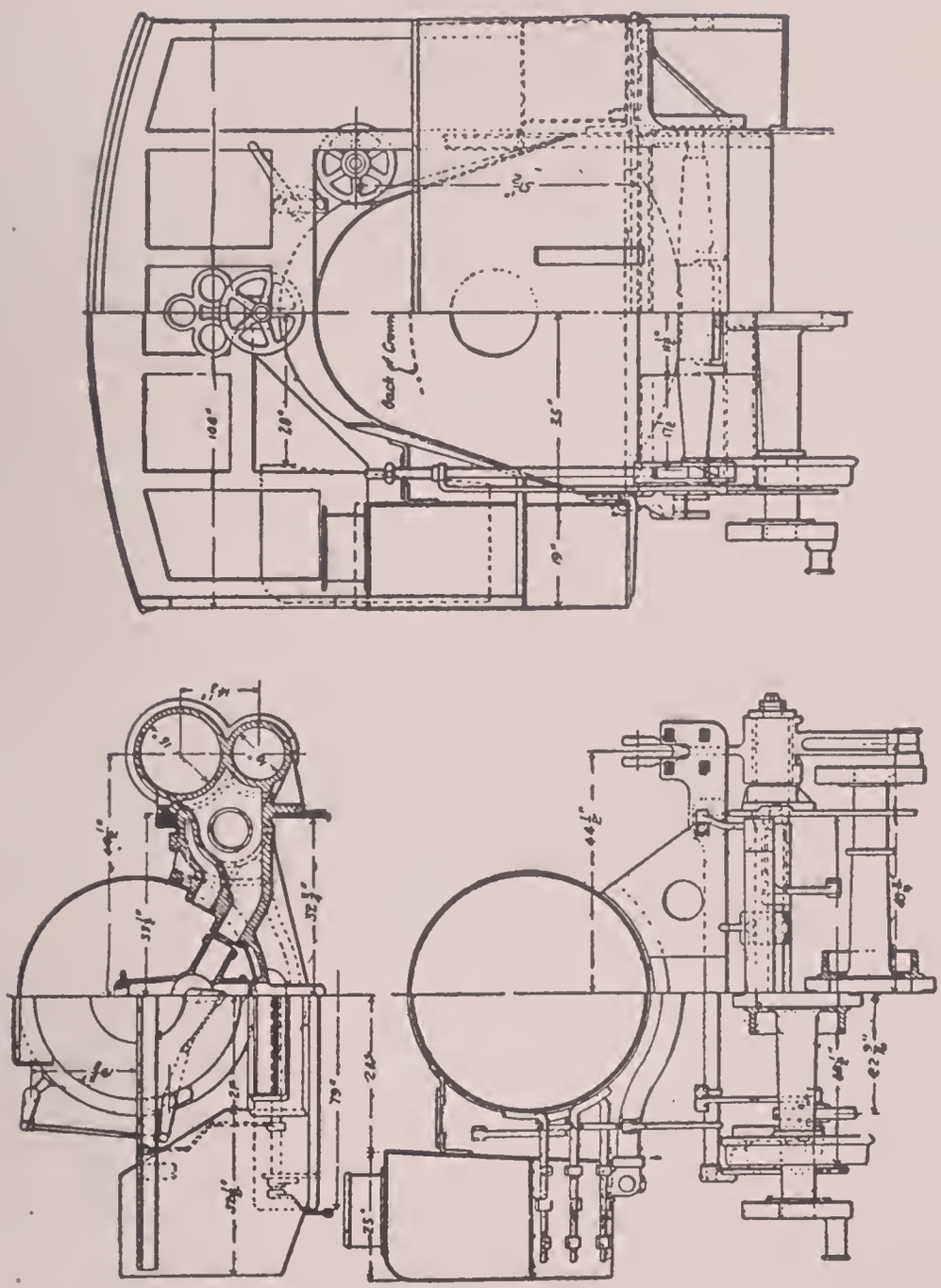


Fig. 2. Rack Rail Locomotive for the Manitou and Pike's Peak Railway—Cross sections and rear elevation.

by 24 inches; driving rack wheel, 24.5 inches in diameter on pitch line; water tank capacity, 600 gallons; oil tank capacity, 325 gallons; grate area, 19.7 square feet; total heating surface, 605 square feet; total weight of engine, 60,000 pounds; tractive power, 25,284 pounds.

SETTING VALVES ON A SHAY LOCOMOTIVE.*

In setting the valves of a Shay locomotive the principal point is to obtain the correct central positions of the crank for the different cylinders; after they are found the setting of the valves is the same as on other engines.

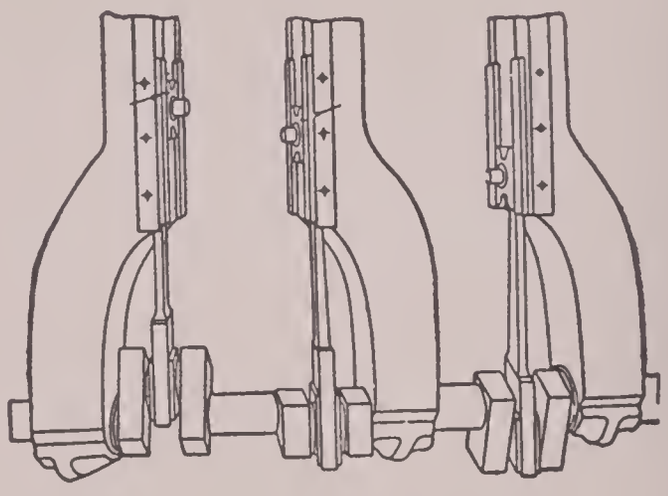


Fig. 1.

To find the central position of the crank for No. 1 cylinder (cylinder nearest cab), roll the crank until the crosshead for No. 1 cylinder is within a short distance of the end of the stroke at the top, say ¾ of an inch, make a mark on the crosshead and guide of No. 1 cylinder while in this position, also on the crosshead and guide of one of the other cylinders that has the crosshead the highest, which will be No. 2, if the pin of No. 1 is back of the center. (See Fig. 1.)

Now, roll the crank till the crosshead of No. 1 passes up to the end of the stroke and returns to the mark; make

*From "Locomotive Firemen and Enginemen's Magazine."

a mark on the crosshead and slide of No. 3 cylinder. (See Fig. 2.) There are now two marks that are an equal distance from the center of No. 1 cylinder and to roll the crank over until the marks on the crossheads of Nos. 2 and 3 are the same distance from the marks on their respective guides, will place the crank on the top center for No. 1 cylinder. (See Fig. 3.) The lower

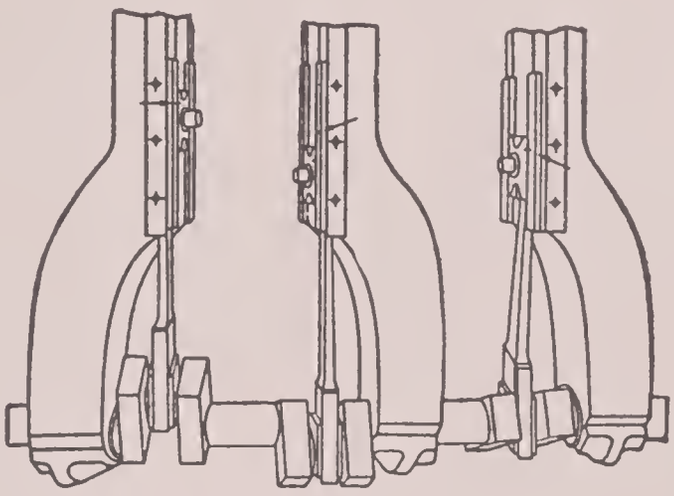


Fig. 2.

center may be found by rolling the crank a half turn, which will bring the marks on the crossheads for Nos. 2 and 3 cylinders an equal distance from the marks on the guides, but the distance will be greater between the marks than when the crank was on the top center. (See Fig. 4.)

The centers for the other cylinders are found by the same operation, using Nos. 1 and 2 to get the center for No. 2, and Nos. 1 and 2 for the center for the No. 3.

To set the valves, place the crank on the upper center for No. 1 cylinder, move the reverse lever to the extreme positions, forward and back, and adjust the eccentric rods until the port openings in these positions are equal and should be about 1-32 inch.

Roll the crank to the lower center and if the port openings are the same with the reverse lever in the extreme positions as they were when the crank was on

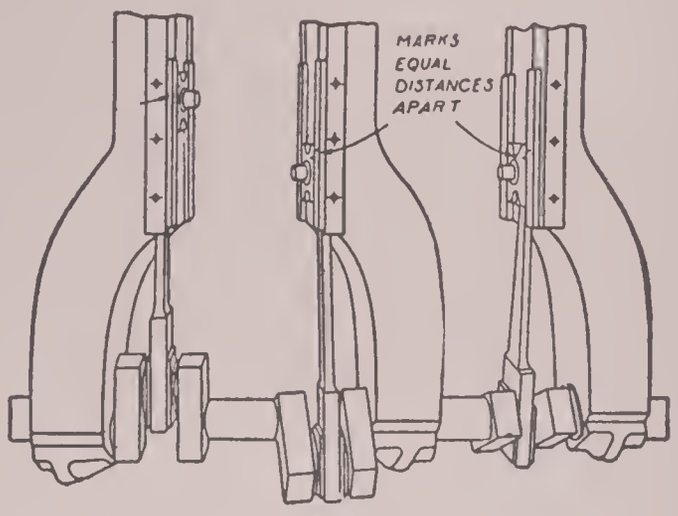


Fig. 3.

the upper center, the valves are properly set. If it is found that the port opening is greater or less on the lower center than on the upper center, the openings may be

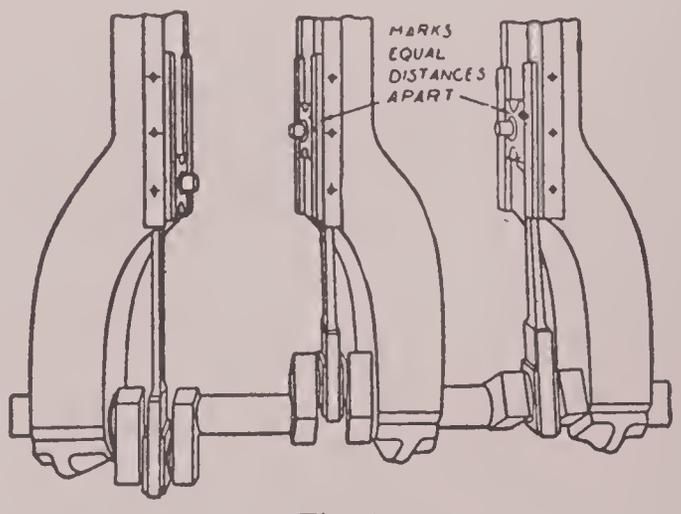


Fig. 4.

equalized by shortening or lengthening the eccentric rods. If there is no lead after the movements are equalized, it would be well to dress the edges of the valve to give the

proper amount of lead. The valves for the other cylinders are set in a like manner. A valve tram is furnished with each locomotive that just fits in the center punch marks on the valve stems and steam chests—when the crank is on the center and the eccentric rods are properly adjusted. In using the tram it is not necessary to remove the steam chest covers to set the valves.

TABLE OF APPROXIMATE NUMBERS FOR VARIOUS PURPOSES.

Diameter of a circle × 3.1416 = circumference.
Diameter of a circle × .8862 = side of an equal square.
Diameter of a circle × .7071 = side of an inscribed square.
Square of diameter × .7854 = area of circle.
Circumference of a circle × .31831 = diameter.
Side of a square × 1.128 = diameter of equal circle.
Square root of area × 1.12837 = diameter of equal circle.
Square of the diameter of a sphere × 3.1416 = convex surface.
Cube of the diameter of a sphere × .5236 = solidity.
Diameter of a sphere × .806 = dimensions of equal tube.
Diameter of a sphere × .6667 = length of equal cylinder.
Square inches × .00695 = square feet.
Cubic inches × .00058 = cubic feet.
Cubic feet × .03704 = cubic yards.
Cylindrical inches × .0004546 = cubic feet.
Cylindrical feet × .02909 = cubic yards.
Cubic inches × .003606 = imperial gallons.
Cubic feet × .6232 = imperial gallons.
Cylindrical inches × .002832 = imperial gallons.
Cylindrical feet × 4.895 = imperial gallons.

183.346 circular inches = 1 square foot.
2,200 cylindrical inches = 1 cubic foot.
Avoirdupois pounds × .009 = cwts.
Avoirdupois pounds × .00045 = tons.
Linear feet × .00019 = statute miles.
Linear yards × .000568 = statute miles.

MELTING POINT OF METALS, ETC.

	Fahr.
Platina	4590°
Antimony	842
Bismuth	487
Tin	475
Lead	620
Zinc	700
Cast Iron	2100
Wrought Iron	2900
Steel	2500
Copper	2000
Glass	2377
Beeswax	151
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